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CSP Exam SECRETS Study Guide

Your Key to Exam Success

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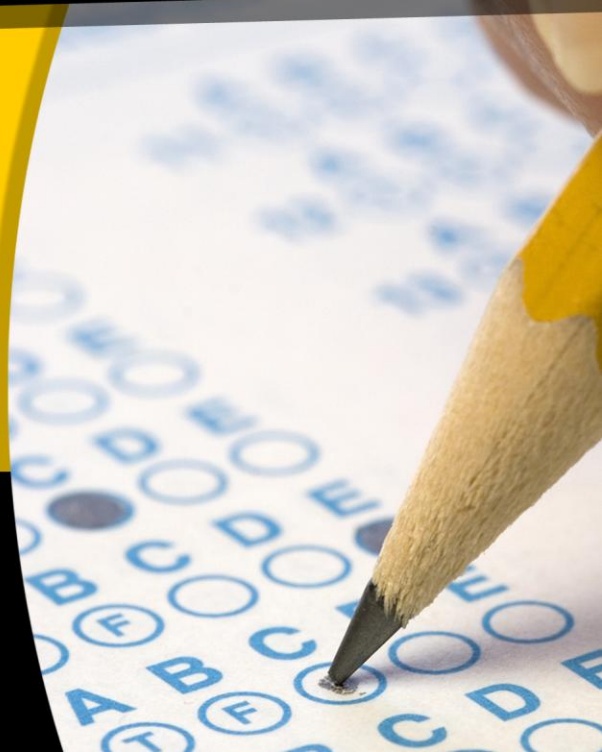
CSP Test Review for the Certified Safety Professional Exam



Published by
Mometrix Media LLC

Dear Future Exam Success Story:

Congratulations on your purchase of our study guide. Our goal in writing our study guide was to cover the content on the test, as well as provide insight into typical test taking mistakes and how to overcome them.

Standardized tests are a key component of being successful, which only increases the importance of doing well in the high-pressure high-stakes environment of test day. How well you do on this test will have a significant impact on your future- and we have the research and practical advice to help you execute on test day.

The product you're reading now is designed to exploit weaknesses in the test itself, and help you avoid the most common errors test takers frequently make.

How to use this study guide

We don't want to waste your time. Our study guide is fast-paced and fluff-free. We suggest going through it a number of times, as repetition is an important part of learning new information and concepts.

First, read through the study guide completely to get a feel for the content and organization. Read the general success strategies first, and then proceed to the content sections. Each tip has been carefully selected for its effectiveness.

Second, read through the study guide again, and take notes in the margins and highlight those sections where you may have a particular weakness.

Finally, bring the manual with you on test day and study it before the exam begins.

Your success is our success

We would be delighted to hear about your success. Send us an email and tell us your story. Thanks for your business and we wish you continued success-

Sincerely,

Mometrix Test Preparation Team

Need more help? Check out our flashcards at: http://MometrixFlashcards.com/CSP

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Written and edited by the Mometrix Exam Secrets Test Prep Team
Printed in the United States of America

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Top 20 Test Taking Tips

1. Carefully follow all the test registration procedures
2. Know the test directions, duration, topics, question types, how many questions
3. Setup a flexible study schedule at least 3-4 weeks before test day
4. Study during the time of day you are most alert, relaxed, and stress free
5. Maximize your learning style; visual learner use visual study aids, auditory learner use auditory study aids
6. Focus on your weakest knowledge base
7. Find a study partner to review with and help clarify questions
8. Practice, practice, practice
9. Get a good night's sleep; don't try to cram the night before the test
10. Eat a well balanced meal
11. Know the exact physical location of the testing site; drive the route to the site prior to test day
12. Bring a set of ear plugs; the testing center could be noisy
13. Wear comfortable, loose fitting, layered clothing to the testing center; prepare for it to be either cold or hot during the test
14. Bring at least 2 current forms of ID to the testing center
15. Arrive to the test early; be prepared to wait and be patient
16. Eliminate the obviously wrong answer choices, then guess the first remaining choice
17. Pace yourself; don't rush, but keep working and move on if you get stuck
18. Maintain a positive attitude even if the test is going poorly
19. Keep your first answer unless you are positive it is wrong
20. Check your work, don't make a careless mistake

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Safety

Within our society a great deal of emphasis is given to the importance of human life and property. Protecting that life and property then becomes a top priority. Three elements that come from this are laws, humanitarianism, and cost. Our society creates laws to protect the safety of people and property. The exact nature and number of those laws is a reflection of our innate humanitarianism. Not only do we desire to protect people in general, but we also believe in the significance of every life regardless of abilities or station in life as well as the right of every individual to own property. Laws related to safety are also designed to limit the loss of property in terms of actual cost. Safety laws are designed to avoid cost of replacing property, lost productivity, and lost abilities.

Company responsibilities

Any company that uses, stores, or transports hazardous materials must use extreme caution to safely handle these substances. Storage of hazardous materials must involve receptacles that are non-breakable, conform to all standards of the Department of Transportation (DOT), and are clearly marked. If these materials are located at an immoveable site, the containers should be in low storage cabinets which can be securely closed and locked. Labeling required by regulatory agencies such as DOT, OSHA, and the EPA must be clearly located on these receptacles and storage locations. Immoveable sites must also display appropriate National Fire Protection Association (NFPA) 704 Diamond signs which allow emergency responders to recognize specific hazards such as flammability and potential health risks from a safe distance. These signs should be located in key areas such as front and rear doors and storage sites. If these hazardous materials are moved from one place to another, the company responsible for shipping must comply with all DOT regulations

An organization's success begins putting policy in place by establishing procedures which cover instructions, training, and education. Procedures must be kept current when

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changes in operations or new systems and equipment are introduced. Procedures should be reviewed regularly to insure relevance and thoroughness and prevent mistakes and accidents. Standardization of procedures is important when equipment and operations involve multiple users such as different shifts. Additionally, procedures might be organized into different levels classified by various conditions such as difficulty, risk, frequency, and required skill set. This allows fine tuning of procedures to meet specific situations. Signatures are also a key part of a successful organization. They provide documentation of job completion, receipt of materials, and acknowledgment of training or instruction.

Accident costs

Direct costs include expenses which are an immediate result of an accident such as doctor, hospital, and other medical costs. Other examples include the expense of fixing or replacing property that was damaged or destroyed by the accident, and payments to an injured employee who cannot work temporarily or permanently.

Indirect costs are also a result of an accident, but their nature makes them less obvious. Examples include cleanup costs, legal fees, and transportation. Additionally, personnel costs, loss of business, and increases in insurance premiums can all result from an accident. Production can suffer during an investigatory shutdown, employee motivation can be decreased, and cleanup time can stop production as well, affecting a company's bottom line.

Federal agency responsibilities

An overview of the responsibilities of the various federal agencies:

- Department of Agriculture (USDA) – conducts research and provides oversight related to food production, agriculture and livestock, and natural resources; regulates pest management, animal pharmaceuticals, and livestock diseases
- National Institute of Standards and Technology (NIST) – conducts research and oversees advancements in government regulation of fire protection and prevention
- Department of Health and Human Services (HHS) – conducts research and develops policies and programs to improve and protect citizen's health

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- National Institute for Occupational Safety and Health (NIOSH) – a subdivision of the Center for Disease Control (CDC) which focuses on creating safe and healthy work environments through research and government standards for employers
- Food and Drug Administration (FDA) – conducts research and oversees production and distribution of food, pharmaceuticals, and cosmetics to protect the health and safety of consumers
- Occupational Safety and Health Administration (OSHA) – forms and enacts minimum standards and guidelines to protect the safety of workers; enforces regulations through regular inspections as well as investigations of complaints or allegations with the power to impose penalties on employers for violations.
- Bureau of Labor Statistics (BLS) – publishes information on safety and health in the workplace based on data gathered from employers regarding job related injuries and illnesses
- Environmental Protection Agency (EPA) – conducts research as well as creating and enforcing standards and guidelines to protect our environment from pollution, hazards, and toxins; seeks to eliminate or reduce pollution in the form of noise, radiation, and hazardous materials.
- Federal Emergency Management Agency (FEMA) – manages crisis response to large scale emergencies such as those related to acts of nature, biohazards, or possible nuclear events by coordinating with state and local authorities; promotes research and training for first responders and creates standard guidelines for crisis management

The FDA is the federal government agency given the primary task of protecting the general public for potential dangers from food, pharmaceuticals, cosmetics, organic products, or substance marketed for healing or treatment properties. Part of this responsibility is to approve certain products for marketing and public consumption. A common application of this role is in the production of new drugs by pharmaceutical companies. The FDA oversees clinical trials, production, and approves new drugs for public prescription and sale. This process can take several years although the FDA has become more efficient in

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recent years. The FDA also has the responsibility to issue and revoke licenses for the production many of these products. These production facilities are monitored and regulated carefully. The FDA imposes standards on the food industry and conducts periodic checks to insure compliance. They can demand that certain products be pulled from stores and no longer offered for sale if a determination of safety concerns has been established and can enforce compliance with these orders.

NHTSA: This federal agency was created to decrease the number of deaths and injuries resulting from traffic accidents as well as minimizing the resulting financial impact, by focusing on accident prevention. The agency looks into allegations or suspicions of problems with motor vehicles that pose a safety risk. The agency has the authority to require automobile producers to fix these problems.

OSHA: This federal agency was created to provide oversight of American workplaces with the goal of insuring worker safety. OSHA focuses on pushing safe work environments that do everything possible to prevent accidents and their negative consequences. This includes the creation of workplace standards, inspections, complaint investigations, and training. OSHA has the authority to enforce national laws related to work place safety. Most workers are protected by this agency with a few exceptions such as transportation workers, miners, and government employees.

The seven OSHA Classification of Occupational Illnesses groupings include:

1. Skin diseases or conditions such as skin irritations, rashes, or burns resulting from contact with hazardous materials
2. Lung conditions resulting from dust including Grinder's disease, industrial bronchitis, and black lung disease
3. Respiratory disorders resulting from exposure to toxins or fine particles such as chronic sore throat, pneumonia, chronic nasal irritation, or farmer's lung
4. Poisoning resulting from exposure to materials such as lead, mercury, pesticides, carbon monoxide, or organic compounds

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5. Disorders or diseases that result from exposure to certain elements or conditions such as radiation or extreme temperatures
6. Conditions resulting from subjection to repetitive elements such as vibration, motion, or force
7. Any other condition not previously categorized, but job related such as hepatitis, cancer, fungal infections, and animal transmitted bacterial infections

The Consumer Product Safety Commission (CPSC) was created to fill the gap in providing protection from dangerous products that are not addressed by other laws. The CPSC considers many products for safety issues and publishes its findings. The agency produces standard testing and investigation approaches and uses these to consider products. In some cases, the agency simply warns consumers of potential risks and even categorizes these risks to further educate individuals. The CPSC has the authority to inspect facilities, run hearings, file lawsuits, and order the confiscation of especially dangerous materials. The agency has the responsibility to notify producers, distributors, and retailers of potentially dangerous products. Products produced within the United States, as well as those imported for sale, are subject to this agency's consideration.

The methods of record keeping for injury and illness used by agencies such as OSHA, MSHA, and the Bureau of Labor Statistics:

These agencies use the logs of injuries and other losses maintained by organizations for yearly inspections. These agencies keep track of work related deaths, sickness, serious injuries, events resulting in limited ability to work, and job transfers related to these types of incidents. Medical care provided for minor injuries is not tracked. However, these agencies do keep track of a worker's lost productivity due to job related sickness or injury by recording lost days and days with restricted duty. Restricted duty implies that a worker is present at the place of employment, but is cannot fulfill all of the job responsibilities, has to be given an alternate job assignment, or cannot complete a full work day. OSHA was the first to start recording restricted duty as an actual loss.

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Federal agency powers

Many of the agencies created by the federal government for oversight of business enjoy broad authority that allows them to create, enforce and adjudicate regulations. Regulatory agencies frequently have the power to establish minimum standards, rules, and operation guidelines that businesses must follow. These agency rules have the power of law. The same agency then has the power to uphold these rules and make sure they are followed. This power is exercised through investigations, inspections, compliance reporting, and other oversight activities. When violators are identified, the same agency can now impose punitive measures. This might include temporary or permanent closing of facilities, confiscation of materials or products, and fines. Appeals of agency decisions in most cases are heard by the governing board of the agency. While an efficient method of government oversight, it lacks fairness and an unbiased perspective.

NFPA 704 Diamond system

Reading the National Fire Protection Association (NFPA) 704 Diamond system for labeling hazardous materials involves a basic diamond shaped sign divided into four equal parts. Each part is color coded for specific hazard and numbered to show the level of risk. A number ranging from zero to four is located in each section with the lowest number indicating the lowest risk and the highest number indicating the highest risk. The top part is colored red to indicate a fire hazard. The right section is colored yellow and indicates the potential instability of that material. The left portion is colored blue and shows the potential health hazard associated with the material, primarily in a fire situation. In each of these three sections a zero would indicate no hazard in fire or water conditions. A four would indicate the highest risk of flammability, combustion, or health hazard, even under normal conditions. The bottom, white section documents special hazards using only two symbols. "OX" indicates an oxidizer which is highly combustible and "W" with a horizontal line indicates potential extreme reactions to water.

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DOT warning label system

The DOT mandates that hazardous materials being transported on roads be marked with the approved warning labels or sign. This label or sign is a 4 X 4 diamond shape that is color coded and marked with a class number at the bottom of the sign for further identification. Class numbers are broken into sub-classes that can dictate the use of certain signs. Additionally, some signs contain written descriptions or warnings. The signs must be placed on all sides of a vehicle. This system aids emergency workers respond safely. Emergency Response Guidelines, published by the DOT in joint effort with the transportation authorities of Canada and Mexico, can be referenced for detailed explanation of signs.

Color Coding	**Class Number Identification**
Red = flammable gas or liquid Orange = explosive material White = poisonous Black & White = corrosive Yellow = oxidizer Green = non-flammable gas Yellow & White = radioactive	1 = Explosives 2 = Gasses 3 = Flammable liquids 4 = Flammable solid 5 = Oxidizers 6 = Poisonous or diseased 7 = Radioactive 8 = Corrosive 9 = Other dangerous materials

Voluntary vs. mandatory standards

Voluntary standards are often developed jointly by members of the regulated industry, relevant government agencies, and concerned citizens. Voluntary standards often represent the lowest or minimum level that all concerned parties can agree to. Individual companies can choose to participate or use this standard in production. Mandatory

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standards are those imposed on industry by the government. These present a minimum standard that industry must meet, enforced by a government regulatory agency. This step is usually taken to address a safety or health issue that is critical, but ignored by some or all of the related industry. Many times the government has to impose this type of standard because of resistance from industry due to the financial burden of making the required changes. Mandatory standards are often established to protect the environment, worker safety, and responsible use of resources.

Laws and regulations

The USC (United States Code) is a collection of all federal laws. Laws are recorded by name and number and grouped according to subject under fifty titles. The code is then further subdivided. Efforts are made to eliminate laws that have been repealed, have expired, and sections that have been changed. General laws that are permanent are usually codified into this record. The USC is fully revised every six years and annual updates are issued in between. It can be accessed digitally. Criminal laws deal with offenses against the state or its citizens. This area involves violent or non-violent crime. Convictions under criminal law can lead to fines or jail time. Civil law involves disputes between private individuals. This area involves personal injury, contracts, and property disputes. Judgments in civil cases can involve court ordered actions and financial penalties. Most laws that affect safety and health are considered civil law. A commonly applicable civil law to safety and health is the Occupational Safety and Health Act of 1970 (OSHA).

The Code of Federal Regulations (CRF) is a publication of all regulations that are created under the authority of the executive agencies of the federal government. It is categorized by fifty subject areas and updated each year. The entire Code can be accessed electronically using an index and site provided aids. This code is organized by subject area titles and specific regulation number. Regulations affecting safety and health can be found under several titles. Most regulations related to the Occupational Safety and Health Act (OSHA) can be found under title The Federal Register is a publication of proposed, amended, and newly approved regulations as well as notices from federal agencies and

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executive orders. It is published daily by the Government Printing Office and is also available electronically. The Federal Register represents changes that will eventually become part of the CRF at its annual update 29.

The Clean Air Act of 1970 was enacted with the goal of improving outdoor air quality in order to safeguard people's health, stop negative effects on agriculture, and make visibility better. The main target of this law is the emissions produced by vehicles such as cars and buses as well as manufacturing facilities. The Clean Water Act of 1972 was passed with the goal of improving water quality by reducing the amount of toxic and hazardous materials that manufacturers release into the environment. The Safe Drinking Water Act of 1974, further improved water quality by establishing minimum guidelines for taste, aesthetics, and color of drinking water supplied to the community.

Workers' Compensation

Workers' Compensation laws can be divided into two categories: elective and compulsory. Laws that are designated as elective allow employers to choose whether to participate. Participation is highly recommended and failure to follow these laws can subject employers to costly lawsuits. Compulsory laws dictate that employers must follow all parts of the law or be subject to penalties. The primary goals of workers' compensation laws are:

- Promoting practices and policies that prevent accidents
- Facilitating thorough investigations
- Promoting employer motivation to protect employee safety and heath
- Reducing the monetary burden associated with workplace accidents and illnesses
- Resolving problems quickly and without costly legal battles
- Assisting injured or ill workers with required medical care and lost wages

In a case where a worker is unable to work due to job related total disability, benefits would begin with complete and unlimited medical coverage related to the incident. This would cover expenses such as doctor visits, hospital stays, surgeon's fees, medications, and therapy. The worker would be eligible to continue to receive a portion of his average

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wages. This percentage is usually around 66%, but the amount is affected by the nature of the disability, the number of dependents for which the worker is responsible, and the workplace. If a job related death occurs, a surviving spouse and/or children are eligible to receive benefits. This would end if the spouse remarries and when children turn 18. Benefits would also be paid towards funeral costs.

Expenses under workers' compensation programs amount to billions of dollars annually. Almost half of this covers the cost of compensation for injuries and lost wages. Almost a quarter is spent directly on medical care and the remainder covers administrative costs. The program is funded through employer contributions based on a number of factors. Each employer's rate can be different and is affected by number of employees, salaries, type of operation, and specific work activities. There are also rate differences between states. The National Council on Compensation Insurance, a private organization, determines rates employers will pay. The NCCI studies trends and conducts research in worker safety as part of the process. Based on state and federal law, some employers are required to carry workers' compensation coverage while others are allowed to create their own, self-funded systems.

Injury claims

Three common law defenses that employers can use to protect themselves from on-the-job injury claims include:

- Assumption of risk: This defense suggests that if an employee understood and freely choice to accept a risk associated with the job, the employer should not be held responsible if the employee becomes sick or hurt because of that risk.
- Contributory negligence: This defense is often used in cases where there is evidence of employer negligence or fault contributing to an accident, but there is also evidence that the injured employee acted in such a way that also contributed to the accident. This defense is often used when the assumption of risk is inapplicable.
- Fellow servant rule: This defense is often applied when other common law defenses are likely to fail. It attempts to prove that another worker's negligence was

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responsible for injuries suffered by the hurt employee, and the employer should not be liable for compensation.

Negligence claims

Negligence claims arise from the concept that manufacturers are automatically constrained to use great caution when designing and producing their goods to insure that consumers or users are not harmed. In order to bring a successful negligence suit against a manufacturer, a plaintiff must show that the product in question was defective and that this condition was present in the product when it left the manufacturer's possession. Additionally, the plaintiff must demonstrate that harm or injury was actually caused by this defect. This is the entire burden of proof in strict liability cases. However, to support the claim of negligence, it must be shown that the defendant knowingly allowed the defect to exist or the conditions that contributed to the defect. In cases involving employee claims against an employer, a common defense is the charge of contributory negligence if the employer alleges the employee himself exercised a lack of caution that contributed to the injury.

Negligence is challenging to prove and the specifications of the Second Restatement of Torts, Section 402A, does not require a plaintiff to meet this burden in a strict liability case. The focus of this type of case is injury alleged to have resulted from a specific product. In order to prove strict liability, a plaintiff must show three basic levels of evidence about the product. They must show that the product in question was defective, that the defect was present when the product departed the defendant's possession, and that the identified defect directly caused injury to the plaintiff. Defendants in strict liability cases will not have the opportunity to offer hazard controls, safety systems, or quality control programs as mitigating factors. Additionally, plaintiffs do not have to show that warranties were violated and disclaimers will not protect defendants from liability.

According to the Express Warranty Principle, an action contrary to a written or verbal promise that results in injury can expose the individual committing the action to legal

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liability. To prove this liability, the plaintiff must show that a contractual agreement was in place between himself and the defendant. The plaintiff must also demonstrate that the defendant did not follow through on a specific promise related to this agreement and that this failure resulted in the plaintiff's injury. In breach of Express Warranty Principle cases, defendants often use one of the following defenses:

- Contesting the existence of a contractual agreement between the plaintiff and defendant
- Contesting the generation of the alleged promise
- Asserting product or service disclaimers or restrictions that the plaintiff surpassed
- Asserting the product or service in question had exceeded the noted expiration date

Three common defenses that are used in response to consumer claims of negligence include:

- Contributory negligence – asserts that the defendant's own actions or failure to exercise reasonable caution were a contributing factor to the resulting injury and it was not solely the result of the defective product in question
- State of the art – asserts that at the time the product in question was manufactured, its design was the safest option available, in other words it was "state of the art"; no better or safer technology and/or resources were available at the time of production
- Undetectable defects – asserts that the manufacturer used all reasonable care in the design process of the product in question, including analyzing safety aspects, but the detects were undetectable; the defense requires the defendant to produce detailed documentation of the design process and safety testing

Liability claims

Privity of contract is a legal concept acquired from English law which states a contract can only obligate the agreeing parties or individuals to the terms or conditions that it contains. This concept has been applied to legal claims against manufacturers in a variety of scenarios including negligence claims. Established legal precedent in the United States based on privity held that if a manufacturer sold a product to a retailer who then sold it to a

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consumer, the consumer could not hold the manufacturer liable for a defect. This precedent was overturned in the 1916 court case MacPerson v. Buick Motor Company. The court determined that privity did not excuse the manufacturer from exercising reasonable care for the safety of a product's ultimate purchaser. The ruling placed greater liability on manufacturers and no longer allowed them to escape responsibility for defective products they did not directly sell to consumers, based on privity.

A certified safety professional's (CS) friend solicits design advice in building a new porch and stairs. The CSP offers suggestions on construction. A few months later, a visitor falls climbing the stairs to the porch. The CSP is now exposed o potential lawsuits because he is professionally liable since he provided consultation on the construction of the stairs and porch. Professional advice leads to professional liability. In order to insure accountability for injuries or illnesses causes and contributing factors for accidents must be determined and appropriate controls and safety devices implemented. An example might be a situation where a worker suffers a broken leg after falling from an extension ladder that was not locked in place. An evaluation of this situation should look at safety programs, management, warning devices, employee actions, and training. In this example, it might be determined that the worker has not received adequate instruction in using the ladder and did not know the proper technique for locking the extension in place. Training programs and employee work environment should be reevaluated and altered based on this new information.

Fire service and mutual aid agreements

In the United States, publicly funded fire departments are responsible for the majority of fire related duties. Responsibilities of public fire departments include fire prevention and suppression as well as compelling compliance with ordinances and laws related to fire services. These departments often offer informative seminars and training for members of the community. This can range from fire prevention tips to CPR certification. All members of the community depend on service from public departments, including residential, commercial, and large-scale industrial. It is also common for companies, especially with

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large operations, to designate employees who lead in the area of fire safety. This role can include training other employees, performing routine inspections for fire hazards, and conducting fire drills. Mutual aid agreements are reached between fire service providers, stipulating that they will help one another in emergencies. This can benefit both groups by reducing the costs associated with labor and equipment.

Management approaches

According to Grosse a successful organization possesses talented leadership, effective communication, and a strong desire to work cooperatively for the organization's success. Within this organization, management has the responsibility to progress toward the organization's goal by acquiring all needed materials and orchestrating their transformation into whatever product or service is being created. There are three important components to this process: performance, scheduling, and cost. Performance is the identified goal to be achieved. Scheduling involves the efficient and effective management of materials and manpower. Cost is the financial outlay needed for the materials and manpower. According to Grosse, success depends on the ability of management to support and supervise each of these three legs.

Safety factor and safety margins

Safety factor is a formula designed to reduce component, product, or system failure related to poor design, defects during production, or product breakdown. Safety factors accomplish this by determining a product's minimum strength and maximum allowable stress. Safety factor is commonly shown as a ratio of failure producing load over permissible stress. Safety factor also considers that increasing product strength can still result in malfunctioning and elements such as material uniformity and potential damage to products can also affect failure rates. Safety margins are used to measure the difference between a product's minimum and maximum strength using the following ratio: (minimum-maximum strength) over minimum strength. A safety margin should also be a positive number. Negative safety margin values indicate a high risk of malfunction.

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Analysis and simulations

Past experiences can be analyzed and used to construct simulations that can predict future outcomes. This is valuable for designing safe products and systems, understanding interactions, and training workers. Simulations allow products and systems to be testing under certain conditions. Reactions and effects can often be extrapolated to similar products, systems, and materials. Computers play an important role in conducted analysis of past experiences and building simulations since they can develop a wide range of potential scenarios and conditions and well as incorporating analysis data to predict responses and effects. Simulations can provide valuable data, but are dependent on the different components and materials actually reacting in ways that are predicting by past experience, analysis, and computers. Simulations also allow limited testing of products and conditions without exposing people to the risks involved in other types of testing.

Safety audits

A safety audit is conducted with the goal of closely examining an organization's foundational practices, policies, and procedures. Safety audits are initiated with the goal of improving a safety within an organization by reducing risks and eliminating or minimizing recognized hazards. Depending on the organization, auditing may be conducted by a third party or by company employees. The auditor will analyze past performance of the entire organization and specific divisions or managers and offer suggestions to improve future outcomes. The auditor will present a number of questions to relevant employees and managers regarding hazardous materials, training, safety plans, crisis response, as well as documenting their own observations.

Regular audits and reviews are an important component of the overall safety program as a supplement to the daily safety operations. Audits can determine if a safety program is working as anticipated as well as monitoring employee compliance with the program's directives. Non-employees such as subcontractors and vendors are auditing for safety compliances in addition to regular employees. Audits examine different areas closely in addition to considering the big picture. This process examines how safety guidelines are

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used in the organization's operations. Audits and reviews look for new risks and hazards and insure processes are in place to continuously monitor for unknown problems. Audits check for that remedies have been put in place for identified problems.

Members of management, boards of directors, special committees, and third parties, can all conduct organization reviews. A review is a critical look at identified problems, proposals, or design plans. This process allows a more objective look at organizational practices. There are different types of reviews. Interdisciplinary reviews consider a number of operation components, including safety. These are often completed by systems engineers or system designers. This type of review looks at each part of the operation. The review offers a chance to make changes to the system design as well as simply checking that each part of the operation is being carried out as designed. Some reviews are conducted to consider safety programs and elements only.

Safety analysis

A safety analysis is conducted in order to improve understanding, assist the decision making process, and meet the requirements of government legislation and regulatory controls or contract stipulations. Prior to commencing a safety analysis, individuals should establish the depth of the analysis and what it should accomplish. Safety analysis is often conducted in order to gain insight into the interaction of various elements in a system or operation in order to improve the overall safety. Safety analysis is a tool that managers can use to guide decisions regarding equipment, operation procedures, employee management, and funding. Local, state, or federal mandate may require certain use of safety analysis and non-compliance can often result in costly fines or penalties. Safety analysis can also be a component of contracts created between an organization and its employees, unions, suppliers, or customers.

Accident investigations

Accident investigation is one type of safety analysis. A component of the investigation is to consider the factors that contributed to the accident and what controls might prevent a

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similar reoccurrence. Accident investigators compile a significant amount of data related to the accident including causes, resulting injuries, loss, or damage, legal evidence connected to related lawsuits, and complicating factors. Accident investigations associated with insurance or legal claims might focus on assigning responsibility. Accident investigations unrelated to these areas are less concerned with blame and more focused on developing proactive strategies as a result of the information gathered.

Accident investigations fall into two categories. The most common type used in industrial operations is general accident investigation. This type of investigation utilizes observations, narration, and witness or participant interviews to gather data about an accident. The goal would be to identify causes or contributing factors of the accident and develop new procedures or safety controls that would reduce the chance of similar incidents in the future. This type of investigation might be documented in a narrative report by a supervisor. A specific accident investigation is more common in vehicular or transportation accidents as well as those involving fires. This type of investigator would need more specialized training and knowledge. An example might be the investigations of airplane crashes conducted by the NTSB. These investigations might be lengthier in duration and are very focused on specific elements of a particular situation instead of general procedures.

Accident investigation is typically a multi-step process with each step influenced by the others. Discoveries in the course of the investigation determine the path the investigation will follow and some steps can occur simultaneously. Accident investigation begins with notification that an incident has occurred. Additional steps include initiation, fact finding, analysis, interrogations, findings, and reporting. Analysis is an important element of the process since it draws all data together in the formation of conclusions. Some investigation, such as auto accidents, often involves computer software. Written reports are generated to document all steps of the investigation, describe data gathered, techniques used, and conclusions reached. Accident investigation seeks to use written reports to prevent similar incidents in the future.

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Accident investigators utilize simple tools like notebooks, sketch pads, scene tape, and rope. The scene tape keeps individuals not involved in the investigation away from the area. Sketches are commonly made and investigators often use still and video cameras to preserve evidence and document interviews with witnesses and those involved. If an accident involves radiation, Geiger counters are used. For chemical mishaps, colorimeters and other direct reading devices are utilized. Spills and contaminations might necessitate containers, measurement devices, and labeling tags. Legal guidelines and mandates sometimes determine what must be gathered and investigator must be knowledgeable.

An accident investigation has many stages leading to analysis, which is the most important. A number of different techniques can be utilized including fault-tree analysis, management oversight, and computer resources. Certain computer programs can be used to reconstruct the elements of an accident for closer evaluation. Gathering evidence leads to analysis from which investigators must reach conclusions about the elements of the accident for current action, and future prevention. This evidence is present in a variety of reports about those involved, procedures followed, information gathered, techniques used, and results identified. These reports and the resulting analysis help those in a position to make change suggest actions to prevent similar occurrences in the future by changing policy, procedure, training, and requirements.

Safety engineers should determine ways to reduce the number of accidents as well as lessening the damage produced if an accident does occur. The following techniques can be utilized:

- Isolation – is a way to lessen the damage that is generated in an accident. Examples of this include using energy absorbing devices to protect workers and machinery. Also, in cars, drivers and passengers are protected with bumpers and air bags and packing components are used to protect materials during shipment.
- Personal protective equipment is utilized to keep workers safe in the event of an accident or minimize damage from unintended events. This could include items

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such as ear plugs, fire-resistant suits, respiration devices, cutting gloves, and goggles.

Inspections

When safety analysis is used to prevent accidents it is referred to as an inspection. Inspections can fall into several different categories. Detailed inspections are designed to be specific to the actual equipment or operations that are being reviewed. General inspections consider a broader range of potential problems. Detailed and general inspections are often conducted at regular or scheduled frequencies or prior to the completion of certain tasks. Unscheduled inspections are conducted without prior notice and can take place during regular detailed or general inspections. An example is an airline pilot who conducts a general inspection prior to each take off. Airline mechanics conduct regular detailed inspections on each plane, examining all equipment and systems carefully while following specific guidelines. During a schedule repair or maintenance activity, an airline mechanic might conduct an unscheduled inspection of a related component.

Accountability

The first step in establishing accountability for safety within an organization is the publication of clear standards for all employees. There should be established rules, procedures, and guidelines on which every employee is trained. Owners and managers within organizations must take steps to provide all needed resources to ensure safety. Safety can be strongly promoted within an organization by incorporating it as a component of the annual performance appraisals for management. Raises, bonuses, and promotions can provide powerful motivation for managers to make safety a top priority. Reviewing records for safety and management procedures for promoting safety as an element of job performance creates written accountability for supervisors. Safety compliance and promotion can even become an element of every employee's evaluation process. Positive reinforcement should be offered in the form of financial incentives, public recognition, or job status. Clearly defined negative consequences should also be in place for safety violations.

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Accountability is based on monitoring the safety records and compliance of employees and using this information to make decisions about employee status. Research has noted the correlation between using safety performance as a factor in bonuses, raises, and promotions and improved safety records. Accountability can often be measuring using a cost accounting system which factors in the financial aspect of safety and uses this data to directly impact employee job status and benefits. Another approach is a motivation program that places less emphasis on the current and past history and focuses more on future results. Establishing accountability through cost accounting, proactive safety programs, and appropriate training for new workers and ongoing training for existing workers can lead to a reduction in the number accidents.

Safety programs

Just like all other aspects of production, safety programs will have specific costs associated with their implementation. In order to justify the expense of some or all of the components of a safety program, those expenses must first be identified in an easy to understand format. These costs must be analyzed to determine if their potential benefit to the organization is justified. Alternate programs or options should also be considered, both from a cost and benefit perspective. This also means considering the potential cost or loss of benefit that might occur from not financing the safety program. As an example, before deciding that installing a sprinkler system in an older building is too costly, an organization should consider the potentials costs incurred. This could include increased insurance premiums for lost safety discounts, lengthy period of ceased operations if fire destroyed the building, and even the loss of life that could occur in an uncontrolled fire.

There are a variety of components within an occupational safety program. First, workers must be knowledgeable about dangers and risks associated with their workplace as well as procedures for staying safe and healthy on the job. This includes understanding and correctly using protective equipment, devices, and clothing. Some workers will be required to work as inspectors during normal operations and be prepared to take initiative in crises or emergency situations. Within an Occupational Safety Program, components should

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include program objectives, training curriculum and activities, documentation and active monitoring of training, training assessment, and regular program analysis. The program should include awards and incentives for compliance and success.

Detail

Designing an effective safety plan is only the first step. Success requires that close attention be given to every detail. Organization workers need to be motivated to embrace the plan. This means employees must be educated and trained in every aspect of the plan, frequent feedback should be given to employees regarding adherence to the plan. This can be as simple as quick verbal feedback or an email or as detailed as regular evaluations. Management should be supportive of employees and recognize efforts and achievements. Frequent reminders regarding safety plans should be incorporated into the work environment. This can be weekly or monthly newsletters, emails from a high ranking company official, and posting motivational signs. An example of this is to prominently post signage detailing the number of days without an accident. Management and supervisors should regularly observe the work environment for potential hazards and signs of worker non-compliance. Safety should be prioritized at every level and managers should never assume that those working beneath them are following the plan. Supervision is the key.

Managerial tasks

A product safety program requires effective management to accomplish its goals. Management control and responsibility are key elements to this process. A product safety program must include the following tasks:

- Creating guidelines and mandates on the organizations product safety policies
- Assigning responsibility for every level of coordinating and carrying out safety programs
- Overseeing the development and continued use of training programs related to safety programs for all employees
- Educating personnel about the goals and underlying principles of the organization's safety program

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- Conducting regular inspections for compliance with assigned responsibilities and time frames
- Financial planning to fully fund all activities related to the safety program

Technical organizations involvement

Technical organizations can improve product safety in the following ways:

- Using data gathered through the use of Failure Mode and Effects Analyses (FMEAS) in reliability engineering can impact quality control by decreasing performance failure
- Test engineering programs can verify that hazard checks are functioning as well as possible
- Field service engineers provide data on the status of a product during manufacturing including the effect of design on safety
- Production engineers oversee the implementation of changes and analyze problems to verify that product safety has not been compromised
- Quality control personnel ensure that employees are following safety program and procedures and working to reduce hazards.
- Technical media authors work to design guidelines that are concise and clear so that all impacted personnel will be knowledgeable about safety controls.

Product life cycle

Concept phase

This is the initial stage where product life begins with a vague plan to develop a new product or change an existing product. During this stage, preliminary calculations are done to see if plan has potential to be carried through and generate profit.

Development evaluation phase

This phase, also known as the "go-ahead" phase, is based on the prediction that the plan for product development will receive necessary approval. Preliminary steps are taken toward design including defining possible design and manufacturing options and use of materials and labor.

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Developmental phase

During this phase, product manufacturing is implemented. This phase is crucial for its significance in identifying possible hazards in production and designing safety plans and manufacturing controls to reduce or eliminate these hazards.

Product evaluation phase

This phase is connected to the development stage and involves analyzing what has been accomplished in the manufacturing. Consideration is given to potential hazards that might be encountered in the future and any needed adjustments are made before mass production begins. Moving forward from this phase, triggers actions to accommodate production, distribution, and involvement of support personnel outside the manufacturing facility.

Production phase

In this phase, since safety concerns have already been addressed, optimal achievement in design and manufacturing becomes the key element. Care should be taken in this stage to avoid design changes that have not been thoroughly reviewed and approved. Such changes can negatively impact product design and safety.

Operation phase

This phase focuses on evaluating on how well safety controls are working in the manufacturing process and ensures the product is being used according to design.

System safety guide

The Military Standard 882B is a guide for safety design that is used in numerous industries and production applications. MIL-STD-882B considers safety design a key component of a variety of systems and promotes the following safety design elements:

- Eliminating or decreasing potential hazards by carefully choosing materials and design elements that will lessen risks during the product life cycle
- Isolating hazardous substances from other materials and people
- Minimizing risks by taking care not to cause harm to environmental elements during the design process

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- Locating equipment in a manner that reduces or eliminates potential hazards when acquiring the equipment such as considering electrical wires and sharp edges
- Designing products and systems to reduce the potential for human mistakes
- Protecting control devices and power supplies through isolation or guarding devices

The document most widely used in industry is the Military Standard 882B. Elements that are addressed in the MIL-STD_882B include: definition, product design, manufacturing, development, and dispersion. It also stipulates that the main safety engineer or project manager should hold professional safety certification. Although intending mainly for interaction with government agencies, M IL-STD-882 is an applicable safety guide for any organization. Safety system elements are prioritized as follows:

- Reducing risks during the design process by avoiding the creation of hazards
- Using appropriate safety apparatus if hazards cannot be removed or reduced
- Utilizing warning equipment and signals if hazards cannot be removed or reduced
- Designing and training personnel in specific hazard avoidance procedures if the previous steps are inadequate or unavailable

Ventilation

Ventilation is used to keep environments free of toxins, keep dangerous gases and vapors from building up, and increase human comfort. If designed appropriately, ventilation can decrease odors, lessen the impact of cigarette smoke, and manage the dispersion of dust, microorganisms, and fine particles of undesirable substances. Ventilation is also used to stop the buildup of carbon dioxide in contained environments with people present. People produce approximately 0.7 cubic feet of carbon dioxide each hour. Ventilation must be able to reduce four cubic feet per minute, per individual, in a space to prevent carbon monoxide poisoning. Dilution ventilation is commonly used to decrease the presence of flammable gases and vapors. This method becomes more expensive as larger amounts of air are needed to dilute the atmosphere of an environment to a safe level. Local exhaust ventilation is used to trap undesired substances at the point of origin before they

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contaminate another environment. This method transports the substances to a designated containment spot.

Principles of an effective dilution ventilation system:

- The movement of polluted air should be directed away from humans
- Fresh air should be prioritized for occupied areas first before being supplied to polluted areas
- Fresh air should be extensively introduced into all areas to decrease the buildup of toxic air
- Fresh air flow amounts should be determined by management of pollutants based on scientific formula

The following formula can be applied to solvents:

total amount evaporated X volume of dilution/one pint of solvent X safety factor

This formula makes the following assumptions or usages. Dilution volume is the amount of air in cubic feet that is needed to reduce concentrations of evaporated solvents to the established Threshold Limit Values. TLV indicates the average concentration of a solvent that is supposed to be safe during an eight hour period and this number varies greatly by different solvents. A safety factor is built into the equation to allow for uneven air mixtures.

Experience modifiers

Experience modifiers are calculations used in determining worker's compensation rates based on a company's loss history. Typically, three of the most recent four years are considered and records of losses are tabulated. This allows companies in the same industry to receive lower rates for reducing actual losses and serves as an incentive for companies to make loss prevention a priority. A formula to estimate losses is developed using class codes for that industry as well as the amount of payroll a company expends. The estimated losses are then compared to the company's actual losses. An experience

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modifier of 1.0 indicates average performance with actual losses coming in close to estimated losses. A number below 1.0 indicates fewer losses than estimated and contributes to lower rates. A number above 1.0 indicates more losses than estimated and contributes to higher rates.

Facility development process

Preferred facility development can be broken into seven steps. The first three steps are as follows:

1. Recognizing the need for the facility is the first step. This involves the perception that current facilities do not meet identified needs. This recognition might be prompted by an incident or loss that highlights the need for better safety or more cost effective changes.
2. Planning the facility is the second step in the process. This includes financial considerations as well. Organizations may choose to use a feasibility study to evaluate specific needs and explore other options for meeting those needs. At this stage all major systems should be considered in relation to safety concerns and needs.
3. Pre-design is the third step which begins when some level of commitment to the project has been established. The organization has decided to proceed with the facility. This step works through more minute details of the proposed facility. Considerations at this stage include location, operations, power supply, and equipment.
4. Design is the fourth step in the development process, occurring after extensive planning. During the design phase, engineer and architectural reports are considered as well as multiple design ideas. This is the appropriate time to build in safety features to reduce hazards and maximize efficiency.
5. Selection and purchasing of equipment is done in conjunction with the design phase. This allows designers to consider safety concerns related to specific equipment and incorporate needed controls or risk reducing features into the facility. Designers work with purchasing staff to obtain resources that meet safety needs.

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6. New construction or facility changes start after the design process is complete and financial arrangement shave been made. During this stage, careful attention should be given to quality control.
7. Occupancy and use is the final stage in facility development. All aspects of design have been implemented and the facility should meet the optimal safety conditions intended by the designers. It is normal for minor adjustments to be required at this point.

Site factors that should be considered for possible hazards when constructing a facility include location, climate, area occupants, population density, and nature. Planning should include evaluations of the state and makeup of the soil and run-off patterns. Pooling water or unworkable drainage patterns can contribute to undesired movement of hazardous materials. Climate conditions such as precipitation and wind can also add to this concern. Residents whose homes or businesses are around the proposed site will bring additional traffic flow increasing the possibility of accidents. Building considerations that should be given priority attention include noise levels, temperature, site regular and emergency access, and air circulation and ventilation. Building layout should be designed for optimal noise reduction, adequate air circulation, and temperature controls. Exit and entrance locations should be adequate for regular and emergency conditions and openings must accommodate any equipment or vehicles that might be utilized in normal and emergency situations.

Work stations and equipment

Work station location, layout, and construction should be designed for the particular job that will be performed. Space should be allowed for easy and free movement from a variety of positions. Seating should be comfortable and allow for personal modifications. The design of the work station should incorporate ergonomic factors such as reducing or eliminating the necessity of bending, twisting, or leaning to minimize the chance of injury. Work station design should also strive to limit the number of times materials are handled. Work station equipment should include safeguards and hazard controls. Additional

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attention should be given to the safety of personnel responsible for maintaining and cleaning the work space. Work station design should incorporate safe access to all stairs, elevators, and different flooring levels. This process should be directed by qualified design personnel trained in safety, not purchasing staff focused on saving money.

Communication

Communication includes the four elements of sender, receiver, media, and message. The sender is the original source of the message. In operations, senders might include a safety engineer or a designer. The responsibility of the sender is to insure successful communication by exercising clarity and conciseness in sending messages. Ineffective communication from a sender can lead to accidents. The message is the intended information to be transferred from sender to receiver. In operations, the message might be related to procedures, design, warnings, usage instructions, or required maintenance. The method of transferring the message is known as the media. Examples can include verbal, email, signage, or publications. Using ineffective types of media to communicate a media can lead to breakdowns in the communication process resulting in accidents, losses, or costly backtracking. The receiver is the intended audience for the message. If any element of the communication process is ineffective, the receiver will not have information intended to prevent accidents, insure safe operations, and properly use and maintain equipment.

Training

A new employee experiences a learning curve when beginning a new job resulting in higher occurrences of accidents. Promptly training new employees in all organization operations is crucial to preventing accidents. A priority training areas is safety procedures designed both to prevent accidents and to guide employees when accidents occur. Organization commitment to safety should be emphasized by conducting safety training separately from general tours, introductions, and training. This prevents safety procedures from being viewed as just another detail. New employees should be monitored closely for compliance with all safety measures and regular feedback should be provided. Retraining and

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remediation should be provided until all safety procedures are mastered and performed successfully.

Regular refresher training can ensure that veteran staff is following all safety procedures as expected. Anytime procedures or equipment is changed, all impacted personnel should be fully trained with the new information. Any change in assignment, job description, or operations also necessitates retraining affected workers. Government regulation of some industries and organizations mandates regular employee training on an ongoing basis, especially regarding handling and proximity to toxic or hazardous substances. Organization supervisors and managers are responsible for knowing and implementing all government and organization requirements for employee training. Additionally, they should personally receive all training required by the employees that they supervise. This enables them to better understand all operations, monitor employee compliance, provide leadership in emergencies, and perform all job expectations if they have to fill in for a missing worker.

Any individuals who will be present in a work environment should be trained in all the related safety procedures. This includes contractors, inspectors, and suppliers. These individuals are often exposed to the same hazards as regular employees and organization owners or management should make knowledge of and compliance with organization safety procedures part of contract agreements. Product users also have an interest in understanding safe use of a particular product. This means an organization should include all related safety manuals, direction for use, and appropriate warnings packaged with the product. This information should be clear and concise and include directions for seeking additional information or asking questions if needed. A way for product users to register for product updates, notifications, or recalls should be provided as well. Organizations should consider the intended market for the product and provide all information in multiple languages as needed.

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There are numerous products and procedures that can pose a hazard to personnel required to use them as well as the general public. Training can reduce some of the risks associated with these hazards. Electric companies post signs warning the public and individuals responsible for repair and maintenance about the location of electric lines and the associated dangers. Further education is provided the public in the form of public service announcements warning of the dangers of digging without asking for utilities locations. Other areas of public education or training in hazards, includes school programs to promote railroad and fire safety. Municipal fire and police agencies often provide safety training in schools as well as producing media materials to educate the general public. Engineers in most disciplines bear responsibility for safety in the projects they design, build, and maintain, a fact supported by a National Council of Examiners for Engineering and Surveying study. It has been suggested that safety be covered more significantly in engineer training coursework.

Promoting compliance with safety procedures can be assisting in the use of materials designed to reinforce desired attitudes and behaviors. Printed media such as posters, newsletters, and flyers can be used to help employees recall safety procedures by keeping the information in sight at numerous locations. Large visual and graphic displays such as posters catch people's attentions and reinforce the organization's message regarding safety. Research that has been conducted about the effectiveness of posters in promoting safety has found that some of the desired poster characteristics include positive language, conciseness, simplicity, and accuracy. Another technique successfully used to promote safety is offering awards or rewards to recognized employee efforts and achievements. This can include verbal praise, simple certificates, cash bonuses, job related perks, or even trips. This technique is based on behavior theories that suggest rewards, especially those promptly given, condition desired behavior. Behavior should be reinforced each time it occurs.

A learning objective is the stated desired outcome of instruction. During instruction, objective mastery would be measured based on the demonstrated behavior or knowledge

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of the student. Objectives focus on desired outcomes, not the process of reaching those outcomes. Establishing and communicating objectives is a key part of training because this enables effective program design including materials, instructors, duration, techniques, and evaluation approaches. Objectives are considered a map to guide learning that facilitate success and reduce confusion, redundancy, and ineffectiveness.

Evaluations provide training instructors with data about the progress of learners and the eventual mastery of training program objectives. Evaluations can be conducted in a variety of formats including written, verbal, and behavioral. All should have the goal of assessing the knowledge and skill of learners as applicable to the program objectives. Evaluations are not a simple cumulative tool, but rather an ongoing component of any training program. Evaluations help instructors shape instruction to meet the changing skill and knowledge level of their students and give valuable feedback on the overall effectiveness of the program. Evaluations help instructors give valuable feedback to learners in order to create a more productive learning environment. Knowledge can most effectively be assessed through written or verbal instruments while actual skills are often best assessed through behavioral observations.

A number of different instructional approaches can be used in adult education. Commonly used techniques include lecturing, demonstrating, question and answer sessions, and rote memory exercises. Techniques should be chosen based on content, instructional atmosphere, and student learning styles. Lecturing techniques are commonly utilized when the goal is to explain or reiterate data that students have already been exposed to through reading assignments, videos, or online research. Demonstrations are utilized in conjunction with lecturing to transition ideas into practice and show real world applications of knowledge. Demonstrations are used to teach procedures, offer insight into how machinery, equipment, or processes work, highlighting dangers associating with certain tasks, and show efficient use of materials and operation components.

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A lesson plan is made up of several different components including objectives, subject matter, instruction techniques, duration, pre-assessment, and final assessment. Lesson plans are constructed specifically to meet the needs of a particular class. In a lesson plans behavioral objectives should be constructed in a clear, concise format. These objectives function as the foundation for the entire lesson and should be specifically stated. A pre-assessment evaluation is a tool used by the instructor to gauge a learner's knowledge, depth of understanding, and skill level as it relates to the content of the lesson plan. Pre-assessment determines each learner's present capabilities, allowing the instructor to tailor the lesson plan to individual students. Pre-assessment is especially useful when a learner is engaging in a structured learning environment for the first time in an extended period.

Organizing subject matter when designing instruction can be accomplished in several different ways. One approach is to organize the information by starting with general, broad concepts and gradually moving to more specific details and processes. This is often facilitated by working around a common theme or main idea from which all instruction originates. Focusing on this main idea allows students to clearly visualize the objectives of a lesson. This approach has the benefit of allowing learners to see the big picture before they focus on the small details that make up that picture. This can improve comprehension, understanding, and recall. Another approach is to begin with concrete ideas and move toward more abstract concepts. Concrete concepts are those which are connected to real, known experience. Abstract concepts build from concrete ideas, but are not as grounded in reality or real experience and can be hypothetical in nature. This approach can be beneficial when introducing new and difficult ideas. Understanding concrete concepts provides a strong foundation for grasping related, but more abstract reasoning and ideas.

When organizing subject matter in a lesson, one method is use chronological sequencing. This involves arranging all elements of the subject matter based on considerations of time, cause and effect, or dates. This approach also emphasizes relationships of different elements. For example, this approach would instruct cause and effect relationships by introducing the casual elements first. Chronological sequencing can also be applied to

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future events and predicted outcomes. This approach has several benefits for instruction including its ease of use based on determining based sequential occurrences. Other benefits include the facilitation of determining patterns, understanding relationships, calculating probability, and predicting future occurrences by studying historical events.

Cooperative learning strategies form a solid foundation for instructing groups of learners in a way that offers specific roles for learners and focuses on the interaction of the participants. Cooperative learning involves three main elements:

- Learners and instructors work in unity toward the same goal. Group goals promote working cooperatively to achieve the same objectives. The work of each group member improves the overall success of the entire group.
- Individual responsibility is a principle that dictates each member of a cooperative group must show growth in skills and knowledge. Instructors promote the use of group effort to accomplish goals, but the need of each individual to maximize effort, participation, and achievement.
- Every learner should have the same opportunity to be successful in the group's efforts. Individual limitations, background, or experience should not limit chances for achievement.

The method used to facilitate cooperative learning or group work should be determined by the objectives of instruction and the makeup and size of the group. Some options include:

- Think-Pair-Share is a method that that builds on questioning sessions with group interaction. The instructor might pose a question to the group for consideration and then have students pair up to discuss their responses. Each pair might then present their discussions to the entire group.
- Pairs Check refers to a technique that pairs up learners in stationary activities. The actual specifications of the activity are not as important as the ultimate goal of emphasizing multiple outcomes to a problem. Students work together, alternating between responsibilities as "solver" or "checker".

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Subject matter is first established and then the instructor can design appropriate learning activities to address and convey that material. In order to reach all learners and address a variety of concepts and skills, multiple activities of varying form should be utilized. Examples include simulations and role-playing, videos, informational reading, rote memorization drills, direct instruction through PowerPoint, lecture, and transparencies, and visuals such as illustrations and graphs. When choosing appropriate learning activities, the instructor should consider individual needs, program objectives, and nature of the material, time limits, and existing skill levels. Instructors can facilitate learner involvement through activities such as presentations, projects, discussion, and interactive technology. The instructor should improve student understanding and success through modeling and demonstrations, especially in specific skills.

Evaluation is a key component of instruction allowing the instructor to gauge the progress of learners toward the identified objectives. Evaluation can take a number of different forms, each focused on determining a learner's knowledge and skills in identified areas. Evaluation can also be a measure of specific, sought-after behaviors. Evaluation can be based on observation, conducted verbally or in writing, or measured in specified performance. Evaluation lets students and instructors know the extent to which instruction has worked. Instructors use evaluation tools to monitor student progress during the course in order to modify instruction and address individual discrepancies in learning as well as at the end of the course for completion purposes and data for future instruction.

One type of instructional approach when training adults in a group is to utilize brainstorming sessions. This method promotes working together to come up with a large quantity of ideas and suggestions. Brainstorming focus on quantity over quality, allowing for later finessing of the ideas produced. The instructor can encourage learners in this environment through suggestion, motivation, guidance, and stimulation while allowing the learners to bear primary responsibility for producing ideas. Another technique is discussion groups. This activity allows the instructor to take a more active role, often

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starting the discussion and contributing throughout. Discussion groups work best when a finite answer is not sought, but rather consideration of a variety of elements, issues, and possibilities. The instructor can phase out his or her significance to the discussion and the learners gain confidence. Discussion groups should be conducted in an organized format that allows full participation and avoids interruptions.

Tutoring is used to address an individual learner's needs that are not being met in regular instruction. Tutoring can be conducted informally or in a more formal setting. Tutoring allows learners to receive more focused instruction that works on their deficiencies in knowledge and/or skills. When tutoring adult students, the following benefits can be seen:

- Individualized instruction better meets the needs of each learner
- Motivation can be increased and struggling learners can overcome embarrassment and fears that inhibit learning and advancement
- Allows for prompt feedback on an individual basis and constant adjustment to the instruction
- Encourages active participation of learners in their own education
- Can be tailored to single students or small groups

A key component of evaluating learners is to verify that they can use data and information to theorize, synthesize, and formulate new ideas. Case studies are one tool used to achieve this. Case studies provide learners with a problem to which they can apply their knowledge and skills. In safety programs, learning with case studies is often facilitated through computer based training (CBT) systems. This allows access to the data and ultimately, the outcome of the case. Learners can use their knowledge to identify miscalculations in the original scenario as well as weaknesses in their own learning. This provides guidance for remedial training and target areas for growth. Use of case studies in a CBT environment reduces the pressures of a traditional classroom setting and provides practice opportunities without real risk.

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Standardized tests are constructed by a supervisory company or agency. They have the benefit of uniform test question type, structure, and complexity as well as administration and grading. Standardized tests are valuable in evaluating progress over a lengthy duration in specific areas of knowledge or skill, but are often broad in scope. Standardized tests usually necessitate training for the individuals who will be administering and grading. Conversely, teacher made tests are constructed by an individual instructor and can be designed to be specific to instructor objectives as well as unique characteristics of a particular group of students or class environment. Teacher made tests are a better indicator of the success of a particular instructional effort.

In an evaluation, objective questions will have only one possible correct answer and that response would be the only correct response for any student taking the test. Objective test items allow instructors to assess a variety of content areas, determine correct and incorrect answers without question, easy connection to objective and have the advantage of quick grading. Additionally, when an objective item is creative, it can be added to a bank for future testing use and their validity is easily determined over time. Objective test items take shorter time for learners to complete than other forms of questioning. Objective test questions do present the following restrictions:

- Guessing can be problematic
- Minutia may be over-emphasized
- Some types of knowledge or skill cannot be assessed
- Creation of questions can take excessive time

Multiple-choice questions can consist of partial statements, posed questions, or math based problems that include several possible answer choices. Choices often range in number from three to five and test takers choose the one that answers the question or problem or finishes the statement. Test takers might be asked to circle the letter of the correct choice, fill it in a blank to the left, or bubble a computer scanned answer document. Multiple choice items have the benefit of easy grading, easy administration, and promoting valid questions which restrict results skewed by correct guesses. Another type of objective test

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item is matching. This is constructed by creating lists or columns in which associated pairs of words, phrases, or sentences are placed out of relation. The test taker must identify the paired information. This has the benefit of easy grading, ability to assess a variety of material, and contains little or no uncertainty as to the correct choice or intended outcome.

In adult education there are three key planning elements to producing a successful experience. The first is to evaluate the knowledge and skill of each learner who will participate in the program. The second is to identify clearly the objectives for the program. These two steps should be completed together in order to provide learners with reachable goals. After the instructor has determined the level of each learner and the objectives for the program, the third step is to create units, activities, and guidelines by which to conduct the class. This can include a course outline, materials to use, sequencing of content, and policies for students and instructors. This element of the planning process facilitates more productive communication between instructors and learners and produces better learning environments.

Critical thinking refers to the process of an individual in forming judgments or conclusions founded on information that has been learned. Critical thinking involves a number of sub-skills such as distinguishing between relevant and irrelevant information, deciphering unspecified expressions, forming conclusions based on limited or obscure facts, and applying learned information to new and unique situations. Instructors desiring to promote critical thinking in learners should focus on student attitude, nature, and tendencies. Critical thinking should be promoted through deeper engagement in the subject matter beyond simple understanding and retention. An important factor in achieving this is the creation of a learning environment where students feel free to take mental risks without concern of peer pressure, embarrassment, or ridicule.
Feedback is an important tool for instructors to inform a learner about his progress toward goals. Feedback also helps instructors fine-tune instruction and course components to help learners reach their goals. Feedback can be offered through a variety of mediums such as simple praise or correction, modeling, pre and post testing, informal evaluations, and

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computer based training systems. Standardized tests are a common method of providing feedback on progress toward more broad and general goals. Teacher designed instruments might be better suited for giving feedback specific to the unique characteristics of the course. Instructors can use available tests or software programs that also allow learners to provide feedback about areas such as instructor style and techniques and course value. Learner success in achieving goals is also a form of feedback for the instructor in assessing the effectiveness of the program.

In the learning environment, each individual presents unique experience, attitudes, values, and desires. Since education involves changing the behavior of learners, the instructor must consider the difference of each learner when determining class objectives, instructional methods, and pacing. Individual differences also create differences in perceptions about the same given situation resulting in different behavioral responses to the same stimulus. Emotions such as fear influence individual behavior in the learning environment. Change is often viewed as a threat since people have developed systems and strategies to move through life. These strategies and systems are reflected in behavior. If someone attempts to alter behavior, they can be viewed as a threat to the way an individual functions. Instructors must consider these factors when planning a program or course. The environment must be safe and supportive of change.

Some general instructional strategies:

<u>Group work</u>

This approach involves several or more learners in cooperative learning and mutual success. Group work is beneficial in producing behavior changes as individuals explore different beliefs, attitudes, and assumptions. Group settings that are informal, non-confrontational, and open produce the best results in terms of behavioral change. This can be facilitated by the exchange of ideas and information which gives a learner alternate beliefs, values, and attitudes to consider.

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Problem solving and personal investigation

This approach allows learner to keep control of their learning by selecting areas of interest to research or pursue enrichment. Instruction is geared toward learner interest and any change that occurs is learner directed.

Activity learning

This approach emphasizes hands-on engagement to stimulate behavior change. Reading about a concept, idea, or action may not be a strong enough influence. Actually engaging in an activity that explores the same can produce more desired behavior changes.

An overall objective of the CSP is to improve the attitudes and actions towards safety within the organization. This means that instruction does not need to be specific or technical in approach allowing for different techniques. A group approach would be ideal for training several individual of similar management or skill level. This could include conference methods, role-playing, and case studies. Conference methods can be casual in nature and improve the positive relations between different levels of employees. The informal environment allows for participant feedback to determine training needs and concerns through question and answer sessions, improving participant recall. Role-playing utilizes hands on and simulated experience to improve learning over more abstract instruction. Case studies allow participants to learn from real scenarios in a variety of safety areas.

Reliability of products

Reliability of a product or its components is an aspect of engineering that focuses on the potential of that product or component to malfunction or breakdown. Reliability is related to product performance, but is connected to safety since product malfunctions can contribute to accidents, injury, and damage. Reliability engineers utilize a variety of techniques to reduce the failure rate of their products or systems. One factor in reliability is derating which establishes lower recommended use levels for a product in such terms as temperature, speed, or duration, to increase its reliability. Less stress and wear on a

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product and its components will result is lower failure rates. Redundancy is another method to reduce rates of malfunction and improve reliability. This approach incorporates multiple components with overlapping functions that maintain product functioning even in the case of a single component failure. This principle is often used in entire systems design.

Parallel redundant arrangements

A parallel redundant arrangement utilizes multiple components in systems, which do not need to work simultaneously for production. Components can alter the function and one component can take over if another fails so that the operation is not interrupted. Both or all components are regularly used in the operation. This approach is most often used in a continuous running unit and most frequently includes dual component arrangements. A stand-by system also has backup components that can be engaged in case of failure of a primary component. However, the stand-by system components are not used, except in the case of primary component failure. This is typically a more expensive approach that parallel redundant arrangements due to the creation of a completely separate system or part. Stand-by systems can also experience problems engaging reliably in the case of primary system or component failure.

Performance assessments

Performance assessments such as quizzes can be used to evaluate the effectiveness of training programs. Instructors should review results of such a quiz to determine if most individuals answered correctly, indicating understanding of the safety program and concepts. Individual questions can be analyzed to insure that they are valid components of the overall assessment. A point biserial score is calculated to determine this validity. As an example, consider the following sample data from a theoretical quiz question:

- Point biserial score of 0.35
- 61% of participants chose “A”
- 13% of participants chose “B”
- 17% of participants chose “C”
- 9% of participants chose “D”

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- "A" is the right choice

Evaluation of this data would indicate that the question was a valid component in successfully evaluated the safety program's effectiveness.

A number of different techniques can be utilized to measure safety performance. Some of these methods are described as statistical because they incorporate data gathering, analysis, and comparison. Statistical methods often examine a big picture or broad trend and do not always hold up to individual cases. In some cases of extremely low accident occurrences, a single accident can skew the statistical results. Statistical methods are commonly used to design safety programs and evaluate worker performance. One type of statistical technique used is a control chart that uses sampling events to provide a basic foundation of data for safety approaches.

Control charts are a statistical tool for examining data to determine if samples considered for forming foundational premises are reliable or simply random. Control charts plot accident data over a set period of time with two horizontal lines marking the range at the lowest and highest levels. The placement of lines on the control chart is determined statistically using deviations from the mean. When evaluating safety performance data such as accidents for a specific individual, facility, or organization, if the value of incidents is outside of the horizontal lines, a problem or unacceptable level of accidents is indicated. This helps eliminate random chance as the factor in the number of accidents.

Two different formulas are used for upper and lower limits on an accident chart.

For upper limits **UCL (upper control limit)** = $x + z_{0.025} S$

For lower limits **LCL (lower control limit)** = $x - Z_{0.025} S$

In these formulas x = mean frequency, z = standard normal distribution on a normal curve with 0.025 probability, and s = standard deviation. Control charts are only reliable if data is arranged according to a normal distribution. Statistical assumptions are not valid if the sample considered is too small. It is generally held that at least sixty sampling periods

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should be used. Significant changes to the operation require a new sampling period to be conducted.

BCSP Code of Ethics and Professional Conduct

The Board of Certified Safety Professionals (BCSP) has established a code of ethics and professional conduct that must be followed by individuals who are awarded certificates by this organization. The first two standards of this code promote the need for certificate holders to support and promote integrity, esteem, and influence of the safety occupation. The code prioritizes human safety and health as the top concern in any scenario. Additional focus should also be given to environmental safety and the protection of property. Each of these priorities can be promoted by safety professionals in warning people of hazards and risks. These standards also include the promotion of honest and fair behavior toward all individuals and organizations and the avoidance of any behavior that would dishonor the esteem or reputation of the safety profession.

Specifically, Standard 1 focuses on the primary responsibility of a certified safety professional (CSP) to protect the safety and health of humans. A specific component of this responsibility is the need to notify appropriate personnel, management, and agencies regarding hazardous or potentially hazardous situations. An example might be a scenario in which a CSP is analyzing company records of employee exposures to potentially hazardous materials on a consultant basis. The CSP discovers a calculation mistake in transferring readings from a personal monitor into a formula that calculates the daily exposure rate. This mistake has resulted in underestimating the exposure rate by as much as 50%. The CSP immediately notes these findings in an urgent communication to the company. He then follows up with the company on correcting the calculation errors immediately for present and future employees and determining actions taken for employees that might already have received hazardous levels of exposure.

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Standard 2 specifically deals with the CSP's character. The CSP should "be honest, fair, and impartial; act with responsibility and integrity…" The CSP has to balance the interests of all involved parties, and represent the profession in all business dealings.

Standard 3 focuses on appropriate public statements and contact. This standard notes that honesty and objectivity are required in all communications and statements. Certified safety professionals (CSP) should only make statements related to areas or situations about which they have direct expertise.

Standard 4 of this code focuses on the professional status and actions of CSP's. A CSP should only engage in projects or activities for which they are highly qualified in terms of knowledge, training, and experience. Additionally, ongoing education and professional advancement activities should be pursued by all CSP's to maintain and improve knowledge and skill level as well as to maintain certification. The Board of Certified Safety Professionals supports annual conferences that enable CSP's to receive valuable training and education while accumulating required points to keep their certification current.

Standard 5 focuses on integrity and honesty in the presentation of professional qualifications. This includes areas such as education, degrees, certification, experience, and achievements. Not only must CSP's be careful to clearly and honestly state all qualifications, but any exaggeration or misrepresentation by omission must also be avoided. When applying for jobs, providing references, or testifying in court, a CSP must not lie about their employment history, professional relationships, or professional qualifications and experience. A CSP with knowledge about violations of this standard should report the information to the Board of Certified Safety Professionals.

Standard 6 specifies that the CSP should avoid all conflicts of interest in order to maintain the integrity of their profession. Section 7 focuses on avoiding discrimination and bias. It is specifically noted that CSP's must not discriminate or demonstrate bias based on gender, age, race, ethnicity, country of origin, sexual orientation, or disability. These areas are also

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regulated by local, state, and federal agencies enforcing Civil Right and other related anti-discrimination legislation. Section 8 of this code promotes the need for CSP's to be involved in community and civic events and use their professional qualifications to promote safety within their own community. Examples of this include instructing public safety personnel in handling hazardous materials, teaching public safety classes in areas of fire prevention, home safety, and accident prevention. CSP's can work cooperatively with organizations and agencies already working in the community such as the Red Cross, fire departments, and police departments.

The impartiality principle of the Board of Certified Safety Professionals (BCSP) Code of Ethics holds that:
A certified safety professional (CSP) should adhere to the impartiality principle in all interactions and engage the advice and support of supervisors in determining appropriate actions. One area of concern is to avoid conflicts of interest or promoting oneself beyond actual expertise or competence. For example, if asked to testify in a lawsuit that revolves around an incident involving a former employee of a company affiliated with the CSP's employer, the CSP should defer to avoid conflict of interest. Another example would be a CSP who is asked to testify to the appropriateness of safety procedures related to radioactive materials. Although the CSP received general instruction in this area in a course, he has no direct experience. He should decline to avoid presenting himself as an expert in that area.

The Code of Ethics and Professional Conduct for certified safety professionals (CSP) notes that the primary responsibility of a safety professional is to safeguard the health and safety of humans as well as providing for the safety of the environment and property. In a typical construction site, numerous organizations, individual, and entities are working jointly to complete the project. Ultimately, each organization or company bears responsibility for making sure its workers are well trained and have a safe work environment. A main function in ensuring a safe worksite is to include safety stipulations in the contracts of all involved individuals or organizations.

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A CSP must earn at least 25 points every five year period, based on continuing education and professional development in order to retain their certificate.

Heinrich's Theories

H.W. Heinrich proposed his **Pyramid Theory** to explain the relationship between accidents and the number and severity of injuries. In his original proposal, Heinrich offered at 300:29:1 ratio to describe this relationship. In a scenario of 330 accidents, one would result in a serious or fatal injury, 29 would result in minor injuries, and 300 would cause no injuries at all. Similar studies have since been conducted, often expanding to consider other impacted areas as well, such as property damage. Although other studies did not exactly duplicate this exact ratio, they did support the pyramid concept which holds that more accidents will result in minor injuries than in severe injuries and more accidents will result in no injuries than in minor injuries.

H.W. Heinrich proposed a theory regarding the causes of accidents which suggests and number of factors can precipitate an accident, each affecting the next, much like a line of dominoes falling. Heinrich believed that by removing one of the factors, the chain reaction could sometimes be stopped. The **Domino Theory** starts with the farthest factors which are social environment or heredity, both of which can influence character traits in an individual such as recklessness, violence, inattention, or spontaneity. Next are dangerous or reckless acts committed by an individual and/or the presence of unsafe conditions. Following this would be an actual accident and then the resulting injuries. According to Heinrich's theory, the actions of individuals are the greatest factor in causing accidents, accounting for about 88%. The next greatest danger comes from unsafe conditions, causing about 10% of accidents. The final 2% is described by Heinrich as unavoidable, often considered acts of God.

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Energy Theory

William Haddon theorized that accidents result from the transfer of energy. The sudden release of large amounts of energy such as tornadoes, fires, automobile collisions, and falls from high places result in injury. There is a direct relationship between the quantity, type, and force of energy, and the nature of the resulting injuries. Haddon proposed managing this energy to reduce or prevent accidents. His suggestions include the following:

- Stop energy from forming
- Lessen the amount of energy
- Keep energy from building up
- Stop energy from being released
- Separate energy from objects or people in could harm using distance or time
- Build a physical barrier
- Minimize energy's impact with softer contact materials
- Strengthen vulnerable objects or people against energy
- Prepare to react quickly to energy's impact
- Rebuild and restore damage caused by energy

Spearman correlation

The Spearman correlation coefficient or rank correlation measures the relationship between two variables in terms of strength and direction. It is statistically shown as "R" and seeks to assign a single number value to the relationship between -1 and +1. The closer this number is to +1, the greater the correlation is that exists between the two variables. A number close to -1 indicates a negative correlation. One possible uses for this method in industry is evaluating system efficiency by analyzing difference performance indicators and quality control measures. Another is facilitating risk management goals by looking at the impact of proactive measures and the results of their intended outcome in terms of loss prevention. This might include variables such as different pieces of safety equipment and the number of accidents.

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Law of safety progress

The law of safety progress holds that an organization will be financially hurt if they produce a hazardous product and fail to remedy the problem. This concept further holds that loss of profit from consumer abandonment will motivate an organization to fix a defective or hazardous product, incurring the initial costs involved in order to protect their long-term profits and viability. Defective or hazardous products can also result in government mandated recalls and liability suits that place heavy monetary burdens on an organization. The law of safety progress suggests that most organizations will take proactive steps to avoid the costly consequences of producing a defective product.

Environments

A partial list of types of environments that can affect working conditions includes:

- Natural environment – is the state of nature including the negative effects associated with weather, dirt, and excess moisture
- Induced environment – is the effects of mankind on the earth including the negative effects of auto exhaust, industrial byproducts, radiation, urban and industrial temperature changes, and vibrations
- Controlled environment – is natural environment altered by mankind such as air conditioning, heating, and dehumidified air
- Artificial environment – is a separate state from nature such as removing air from an industrial process
- Free environment – is the unaltered passage of air; can be a dangerous environment
- Closed environment – is a state where air flow is limited; can be dangerous in confined areas where gas buildup can be deadly

Environmental conditions can create instant problems as well as issues that persist for lengthy periods or are not fully realized until much later. Three examples of immediate problems are heavy rain, lightning, and high humidity. Rains can interfere with electrical devices and high levels of humidity can create uncomfortable working conditions. Lightning can seriously injure or kill workers as well as damaging equipment and starting fires. Conditions that can cause long term problems include sunlight, temperature

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fluctuations, and heat from electrical devices. Sunlight causes materials such as plastic, paint, and cloth to wear out. Constant temperature changes can cause metal fatigue due to contraction and expansion, ultimately leading to material failure. Over time, the heat produced by electrical equipment can cause a breakdown in materials and mechanical failure.

Fault tree analysis

Fault tree analysis is an approach to evaluating advanced systems within a safety program. This approach employs Boolean logic to analyze an incident. Fault tree analysis actually resembles the structure of a tree. The incident being considered is at the top. Factors that influenced the incident are identified and broken down further into causes of the incident. This resembles the branches of a tree. This approach also uses probability to evaluate the incident and other possible incidents. The pattern of analysis is to start with general and use inference and reasoning to progress to more specific considerations, paying close attention to the relationship between an incident and each component considered. After the tree has been built, specific measurements and evaluations of quality of relationships can be conducted. Computers are often used in fault tree analysis for efficiency and effectiveness.

The following fault tree analysis events are defined as follows:

- Basic event – is an incident or element that does not need to be broken down further or evaluated; shown on the fault tree as a circle at the end of a branch
- Undeveloped event – is an incident or element that the evaluator might choose not to consider further and its cause may be clearly understood; on the fault tree it is shown as a diamond or double diamond
- Normal event – is an expected and desired occurrence evaluated based on whether it happened or not; shown on the fault tree analysis as a house shape; statistical probability of this event is usually assigned as 1.0 or 0.0

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- Fault event – is an undesired or unexpected incident of primary concern usually placed at the top of the tree for later evaluation; shown of the fault analysis tree as a rectangle

Fault tree analysis begins with an undesired event as the root of the tree. Expanding outward, are each of the possible causes for that event and those causes. Fault tree analysis is often facilitated by specifically designed computer software. This approach is commonly applied to the design stage of a product or process in order to carefully evaluated potential causes of undesired events. When constructing a fault tree, events are shown as blocks and are connected using gates. Gates are designated as "and" or "or". Fault trees can be simple or elaborate and pay close attention to the relationship among all events shown. A possible situation that would indicate the use of a fault tree analysis is the installation of new safety devices that read pressure on a compressor running a tank of hazardous gas. In order to evaluate the risk of rupture under extreme conditions, a fault tree could be constructed.

An event is a component of a fault tree that shows an occurrence. These occurrences could be routine episodes in an operation or might be component or system failures or problems. An occurrence of failure stops normal production or functioning. In an operation, a track that stops moving is an example of a failure. A fault is an aspect or characteristic of an element or entire system that can lead to an undesired event. In a fault tree, causal events can be divided into four groups. Primary events are those related to an integral part of the system. Secondary events are related to objects or actions separate from the actual system. Primary fault refers to occurrences that are outside routine functions in a system. Secondary fault indicates an occurrence induced by something outside of the system itself. Fault-tree analysis is an important tool for safety professionals to understand causes of accidents and overall operations of a system. Using fault-tree analysis to look at safety can proactively expose possible unintended events. Each component of the fault-tree can be considered to determine what would cause these unintended events. Hazard controls can be implemented to reduce this risk. Considering a chain of events will be most successful if a tree branch is examined either from the top or the bottom event. Statistically, events that

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are connected on the tree by an "OR" gate have a greater probability of occurring while those connected by "AND" gates happen less frequently. Using indicators of probability can allow an analyst to give priority consideration to events that are most likely to happen. This allows quicker response to the most pressing dangers that are present in the system.

Organizing data

Records and reports are important for the following reasons:

1. Many types of reports and methods of record keeping are legally required by local, state, or federal government mandated. Some of these reports and records must be available for inspection and others must be regularly submitting to regulatory agencies.
2. Employee's have a legal right to inspect certain records
3. Compiling data in records and report form can make it easier to identify hazards and prevent safety incidents
4. Compiling data in records and report form can provide needed resources for putting changes in place to improve safety
5. Records and reports are vital in processing insurance claims and in determining the cost of insurance premiums, especially those related to losses.
6. Poor record keeping can subject an organization to greater potential liability in cases of alleged negligence or even deliberate acts of wrongdoing.

Transferring statistical data into a more user friendly format can be accomplished through the use of frequency tables and bar graphs. Frequency tables summarize how often different values occur in a set of data. Values are usually organized by size with frequency amounts indicated. Data can also be subdivided into smaller units to make the table more useable. Graphic mediums are sometimes easier for an audience to understand. This format is appropriate to note patterns or inclinations in the information. The most basic graph to use is the bar graph. The data in a frequency table can be transferred to this format by placing values on one axis and the corresponding frequencies on the other axis. A single line on a frequency table is represented by one bar.

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A scattergram is a type of graph which includes a Y and an X axis. It is commonly used in order to analyze the various correlations that might exist between identified variables. The information related to one variable is shown on the Y axis while information related to the other variable is shown on the X axis. One intersecting point will exist for each pair of variables. The points should be placed uniform distances apart. A line drawn through the points which slopes up and to the right indicates a positive correlation between the variables. No clear pattern in arrangement indicates a small or non-existent correlation. If the line connecting the points has a downward slope, a negative correlation is indicated between variables.

A histogram resembles a traditional bar graph except no space exists between the bars. It is used to graph frequency measurements. Frequency is shown in the horizontal bars with divisions or intervals indicated along the vertical axis. This allows a graphic view of the number of occurrences being measured that fall into certain intervals. Sets of data are referred to as bins. When creating a histogram, careful attention should be given to the width of each bin. Overly wide or narrow bins can give a false impression of the data. Histograms can be valuable tools in quality control management and in the analysis of resource usage by answering questions about data distribution. Common occurrences can be identified as well as patterns and isolated events.

Computers can be used to generate a number of different graphs, charts, or tables to analyze information.

- Line and bar graphs – indicate trends and patterns in data, often focus on categories or periods of time
- Pie charts – are utilized to break down a single idea or occurrence into different sections
- Bar charts – can create a comparison between different categories as well as indicating how pieces build a larger picture

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- Tables – are valuable for organizing a quantity of related data by considering individual pieces or sets

Safety inspectors must accomplish the task of recognizing dangerous conditions and hazardous materials. This requires some level of training. Depending on the complexity of the materials and conditions involved, training and education might need to be extensive and an inspector would be a specialist in that field or area. In other cases, required training might be minimal and employees familiar with the operation can often serve as inspectors.

Measurements

Central tendency refers to the average location of one piece of data from a set. Central tendency can be measured using mean, mode, and median. Mean is calculated by adding all numbers in a set of data together and then dividing the sum by the total number of numbers in the set. Mode represents the most commonly occurring number in a set of data. Median is calculated by placing all numbers in a data set in numerical order and identifying the number which falls in the middle. When calculating the median of an even set of numbers, the mean or average of the middle two numbers is determined. Each of these measures has unique characteristics. The median is easily influenced by disproportionately big or small pieces of data. Mean is equally influenced by each number and is a more common tool in working with statistical information.

An incident rate (IR) is a measurement of an organization's safety record as compared with other organizations. This is one performance area in which OSHA and MSHA maintain records. These rates are then publicly distributed by the Bureau of Labor Statistics. This measurement takes into account job related injuries, illnesses, and lost work time. Incident rates are calculated with the following formula:
Number of injuries and sicknesses X 200,000/total employee work hours

Severity measures (SM) are commonly used by MSHA to calculate the level of severity of injury or loss. Severity measures are calculated with the following formula:

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Total days X 200,000/hours of employee mine exposure

The formulas for both incident rates and severity measures are based on 100 employees working for a full year at 40 hours each week.

Hazard control models

One proposed explanation of the causes of accidents is the Multiple Factor Theory submitted by V.L. Grose. He suggested that accidents were the result of four elements which he labeled the four "M's": man, machine, media, and management. Man includes all humans and their innate attributes such as physical characteristics, sex, skill mastery, level of motivation, and mental state. Machine attributes he considers include actions performed, design and choice of materials, and overall size and dimensions. Elements of media could include the work environment, weather, and building design and attributes. Management includes the governing and primary decision making structure of the organization. Elements of management that are most influential include policy development, effectiveness and methods of communication, and overall techniques. Careful analysis of each of these four elements can reduce accidents.

Strategies of prevention

Three strategies of prevention:

- Frequency strategies – seek to decrease the number of safety related incidents through reviewing incidents, conducting careful analysis, and developing appropriate preventive plans in response
- Severity strategies – focus primarily on incidents that are more serious in nature such as those involving death, major injury, long term disability, impact to many individuals, or significant property loss; reports on these incidents are constructed from the perspective of different work environments such as construction, infrequently occurring situations, and high risk conditions

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- Cost strategies – places emphasis on avoiding the incurring of high expenditures related to incidents; does not make injuries or sicknesses the foundation for investigations or measurements of impact instead focusing on the financial impact

Principles in learning

The principles in learning are:

- Identification of a need is a critical component of learning. Greater understanding and mastery will occur if learners are initially given clear goals and objectives.
- Content to be learned must be arranged in a logical pattern that facilitates the greatest level of understanding. Organization is driven by the content and can vary considerably using patterns such as sequential order, chronological order, and progressing skill level. Organization is sometimes accomplished by designed appropriately sequenced modules.
- Stimulating multiple senses during the learning process addresses the different learning styles that individuals possess. Learning should never be monosensory, but instead include visual, audio, and movement-based applications.
- Learners should be instructed in the defining principles of a topic before being expected to master an actual procedure. Understanding why facilitates understanding how.
- New concepts should be presented in their entirety before learners analyze the smaller parts.
- Allowing sufficient time for learning to occur ensures that individuals can practice new skills or procedures often enough for mastery to be obtained. Lengthy sessions should be interspersed with short breaks.
- Negative and positive feedback should be continually offered so that learners can adjust to their progress. Feedback is most effective when given regularly on small segments.
- In group environments some individuals will coast on the efforts of others and fail to maximize their own learning. Instructors should prompt and evaluate individual participation from every learner.

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- Individuals must be recognized for their movement toward objectives through positive feedback and rewards.
- All learners must be offered regular opportunities to refresh and maintain knowledge and newly learned skills and procedures. Refresher sessions can improve long-term recall.

Behavior

Scientists have a number of different theories related to human behavior. Historically, scientists have proposed connections between hereditary factors and people's behavior such as instincts, automatic reactions, and predispositions. Later scientific trends included examining a person's unique internal characteristics. Some scientists proposed that behavior resulted from a combination of hereditary and situational factors. Hereditary factors might include biological conditions or traits as well as emotional state. Situational factors are made up of a person's immediate environment. In the workplace, this could include shift work, commute time, management style, and aesthetic appeal. Human behavior is strongly influenced by personal motivation, mental state, and beliefs. Well-known behavioralist, Maslow, developed a hierarchy of human needs to explain factors influencing behavior. At the bottom are basic physiological needs such as nourishment and sleep moving up through the pyramid to security, acceptance, recognition, and fulfillment.

Hertzberg's motivation theory suggests that behavior is influenced by the outcome of efforts rather than needs. He identified two types of outcomes that affect behavior: intrinsic and extrinsic. Intrinsic outcomes include personal satisfaction and fulfillment and recognition associated with accomplishment. Extrinsic outcomes include the financial incentives, job security, and working conditions. Herzberg suggested that intrinsic outcomes were the most important to an organization's success. Additionally research has implied that both types are significant.

Vroom's motivation theory is known as the expectancy theory. It is based on the belief that an effort and performance are directly related and individual is motivated to give effort

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based on the expectation of reward. The nature of the reward itself is a key factor. Vroom's theory has three parts. The first is valance or the direction and depth of an individual's needs – what motivates him?

The second part is expectancy or an individual's confidence in his abilities. The third part is instrumentality or an individual's level of certainty that expected rewards will be delivered if he succeeds.

Contingencies

Training for workers often focuses on performing under normal circumstances. Too frequently, training neglects to educate workers about procedures for emergency or crisis situations. This results in workers being forced to make their own decisions about actions at a time when pressure already affects judgment. Employee training programs must incorporate contingencies as an element of job performance. A contingency is a situation involving events that are not typical or routine operation. One area of contingency that is often overlooked is repairs or maintenance performed outside of the normal equipment or operations functions. Possible contingency scenarios include the production of a faulty part, failure to feed materials as expected, overheating, over pressurization, human err resulting in injury, power outage, or structure fire. Contingency training should be included as part of ordinary job training, further incorporated into specialized safety training, and regularly refreshed. This training can be further supported with small group problem solving, postings at all job sites, and management tracking of all training.

Training programs often focus primarily or even exclusively on procedures for routine operations. Neglecting contingency or emergency situations in training programs leads to more severe consequences when these events occur. Workers need to be trained to recognize warning signs of impending malfunctions or system problems such as overheating, over-pressurization, and component breakdown. This allows timely repair, adjustment, or reaction to prevent more serious effects. This type of training is important for any individual who might be present in an emergency or contingency situation. This

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includes regular workforce, management, contractors, maintenance, and cleaning crews. Any contracted workers should have safety training requirements as part of their contracts.

Subsystem failure rates

If a system includes a subsystem with two components, the subsystem will fail to function as intended if both components are not working properly. Components of a subsystem are interdependent. This means that both components must be working and the failure of one will make the entire subsystem malfunction. It also means that individual component failure rates must be calculated to determine the overall subsystem failure rate. If a hypothetical subsystem has two elements which each have a long term failure rate of 1/20,000 trials, the following formula could be used to calculate the probable failure rate of the entire subsystem:

Part A + Part B

1/20,000 = 1/20,000

1/10,000 = long term failure rate of subsystem

Quantitative error prediction

Engineers and safety professionals used different methods to predict possible malfunctions by machinery or people. This process known as quantitative error prediction might be conducted using the following methods:

- Data Store is an approach designed by the American Institute for Research. It is used to anticipate how users will interact with machinery controls and panels both successfully and in error. The approach utilizes a quantity of available related data to consider the time that is required to access and use machinery and seeks to determine factors that can negatively impact user performance. The data facilitates the calculation of probability of certain events.
- Technique for Human Error Rate Prediction (THERP) is another approach designed to evaluate user functions and choices. Compared to Data Store which considers

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independent actions, THERP examines operations and functions that are dependent upon one another.

The use of a quantitative approach in establishing goals is becoming more common. This method does present some problems and has several limitations. This approach uses statistical probability to show risks that have a small likelihood of occurring leading to the implementation of no corrective measures. The complexity of some products and processes can lead probability calculations that are inaccurate. This can create greater liability potential in future litigation resulting from product design. This method also devotes excessive time periods to the evaluation of specific products and their position within safety levels. The quantitative method also utilizes data gathering and analysis approaches that lack standardization.

Mechanics fields

Static mechanics

This field focuses on the forces that are applied to objects or bodies that are not moving. These forces work on fixed objects and do not cause movement. Some examples of materials or application in this field include rivets, welding, bolts, and load-bearing devices.

Dynamic mechanics

This field focuses on forces that are applied to objects resulting in an increase in movement. Movement from these forces can occur in different directions and incorporate impulse momentum and energy generated by these forces. An example might be system components that use pressure to move a liquid through a tube or pipe.

Friction mechanics

This field relates to the effects of objects that move while in contact with other objects or surfaces. Friction mechanics includes forces that enable us to walk, use hands or feet to engage equipment, and provide the power for many automated devices or procedures.

Fluid mechanics

This field focuses on the different characteristics of fluids in an attempt to understand and manipulate how fluids behave. Characteristics that are often the focus of fluid mechanics

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include density, weight, thickness, and the effect of other factors on fluids. This field might consider the function of various fluids such as oil or brake fluid in a vehicle.

Risk and its relevance to operations

Risk is commonly defined as the danger of something happening because of a hazardous situation. Risk is often associated with probability based on specific conditions. In operations risk can be associated with a chance of injuries, property loss, death, or other unintended occurrence. Risk sometimes refers to the voluntary chances that an individual knowingly takes when choosing to use a product such as a skydiver who takes the risk that his parachute will malfunction. In other situations individuals involuntarily assume risks of which they are not fully aware. As a part of operations, organizations frequently conduct activities in risk analysis and risk management. These are useful functions in determining insurance needs, alterations to safety systems, overall design plans, and employee training. One of the primary functions of a risk manager is to balance the financial costs of preventing incidents with the risks those incidents might occur.

Risk management

Risk management is made up of five main goals. These include risk identification, evaluating risks, decreasing risks, paying for the costs of risk management, and oversight of the entire risk management process. Once a loss has been experienced, risk management hopes to obtain the following objectives:

- Maintaining the appearance of social responsibility through public relations campaigns that demonstrate concern for the well-being of employees, associates, and the general public
- Promoting continued organization growth through innovative new products, movement into new markets, and acquiring new divisions
- Keeping organization profits steady by keeping costs in check through operational controls
- Maintaining organizational operations after a loss with no interruptions or materials shortages

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- Securing long term organization survival by achieving all other objectives

The nature of some risks an organization faces makes them impossible to eliminate altogether. However, most risks can at least be lessened by deliberate management action. Risk management often makes decisions on these actions by conducting cost-benefit analysis to prioritize areas that can be most greatly impacted with the least expenditure. This approach involves considering quality and quantity considerations as well as a variety of approaches to decreasing the same identified risk. The costs of any new safety programs or devices being considered are weighed against the potential financial benefit of reducing that risk. A current trend in risk management is to conduct evaluations by organizing risks into classifications using probability or relativity. The common categories are risks that should be eliminated or decreased, risks that can be allowed to exist or cannot be decreased, and risks to be continually revalued.

Risk assessment is one of the elements of risk management. Risk assessment includes determination, appraisal, and analysis of risk. The personal attitudes and biases of individuals involved in this process often impact the outcome. Risk assessment can be separated into two different main areas: risk determination and risk evaluation. Risk determination is the process of using investigative techniques and statistical probability to pinpoint possible risks, the likelihood of a resulting accident, and the potential undesired outcomes. Risk evaluation takes a closer look at the identified risks and can be further divided into two areas: risk aversion and risk acceptance. Risk aversion seeks to evaluation how effective certain safety programs, equipment, or training might be at eliminating the risk or at least reducing it. Risk acceptance analyzes risks by weighing factors such as financial and non-monetary costs to determine which risks are acceptable to the organization and do not warrant action.

The following risk analysis approach combines efforts to maximize designated financial resources in accomplishing the highest or most effective level of risk reduction. It can be divided into six steps:

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- A risk index should be calculated based on analysis of the known risks and controls that are currently in place. This involves generating hazard and control scores for further analysis.
- An initial ranking should be constructed of different departments or identified elements in the operation by determining the relative risk associated with each. The element with the highest risk index often has extensive resources already designated and may not need further attention.
- A percent risk index should also be determined for each element
- Total financial exposure, known as composite exposure dollars, for each department or element should be calculated
- Total composite risk for each department or element should be calculated utilizing composite exposure dollars and the percent risk index
- The final step is determining the final ranking of each department or element for guiding decisions on resource allocation

Chemical risk assessment

The National Academy of Sciences has identified the following four elements of chemical risk assessment:

- Hazard identification – this process considers numerous elements of operations and calculates risks using probability and also incorporates an engineer failure assessment
- Dose-response assessment – details the connection between the number of incidents involving injury or illness and the level and duration of exposure to hazards; this evaluation constructs formulas that describe the relationship of exposure, or dose, to injury and illness
- Exposure assessment – determines the number of people exposed to hazards, as well as the characteristics of that population, and the overall level of exposure
- Risk characterization – this evaluation considers all elements of an exposure and the related information in a single analysis

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Risk management includes the five main elements of risk identification, analysis, reduction, financing, and administration. Risk identification focuses on determining elements or actions that can cause injuries, illness, property damage, or even death. Risk analysis uses measurement tools to calculate different risks and types of risk as well as the severity and probability of those risks. Reduction of risk focuses on putting controls in place to address those risks which have been identified including prioritization. Financing risks is the monetary aspect of risk management in which identified need and available resources are correlated. Financing risks also includes considered the cost accounting of saving money by reducing risks. Administrating the entire process of risk management is a top down process in which an allowable level of risk is established from which all risk management activities are conducted.

Preventing unsafe behaviors

Engineering, education, and enforcement are critical elements in averting dangerous behavior. Human behavior is influenced by a number of factors that make it unpredictable by nature. Engineering should design systems, procedures, and operations that reduce the impact of human behavior on safety. Education is another key element in preventing unsafe behavior. Individuals need instruction on hazards in order to make informed decisions about behavior. Training also provides practice that builds good habits and reduces that likelihood of undesired habits that are unsafe. Part of any safety program is enforcement of rules and procedures. Theories of human behavior suggest that positive and negative rewards for expected behavior are more likely to produce results. Enforcement involves monitoring and investigating individual compliance with all rules and procedures. Positive and negative rewards can include bonuses, recognition, termination, mandatory remediation, and loss of privileges.

Individuals must be informed about hazards and ways to avoid hazards in order to exhibit the safe behavior expected. This information can be communicated to people through a number of mediums including written and verbal instruction, seminars, hands-on training, videos, written operating procedures, signage, and evaluations. Since individual

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performance is contingent upon individual understanding of rules and procedures, feedback is critical to guiding that understanding. This allows individuals to make adjustments to their behavior in order to achieve maximum safety. Feedback can take many forms including informal conversation, formal evaluation, and rewards or incentives. Feedback should be provided at regular points throughout instruction or actual job performance rather than waiting until the end to maximize effectiveness.

During the design process for equipment, operations, and entire systems, engineers must be cognizant of typical human behavior in a variety of situations or conditions. Consideration must be given to all ways that people impact the overall safety. This means that in addition to normal procedures, design must include safeguards for less common elements of operations such as equipment maintenance, cleaning, and installation. Engineers must plan safety programs that consider the varying physical nature of people such as height, weight, age, gender, strength. Engineers must also factor in potential hazards presented by errors in judgment, emotion, and altered physical or mental state. In their overall system design, engineers should maximize safety by increasing dependence on the design rather than on individuals.

Preventing unsafe behavior can be addressed by paying attention to The Three E's of Safety. The Three E's include education, enforcement, and engineering. Education can be formal or informal; keeping in mind that behavior is conditioned or learned. Training programs and employee education give workers knowledge and skills about performing safely at work. This includes educating people about potential workplace hazards, procedures to follow to minimize risk, and contingency plans to follow in emergencies. Enforcement involves demonstrating to employees that procedures must be followed. This requires regular supervision, inspection, and monitoring of workplace actions. Employers can utilize positive and negative reinforcement and feedback to insure compliance. Engineers have the responsibility to predict human responses and product and system functions in designing workplace components that decrease the likelihood of accidents or injuries resulting from certain employee actions. Engineering and design can also create

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systems that reduce the severity of injury and the amount of damage that occurs if an accident does happen.

Job safety analysis

Job safety analysis (JAS) is an approach to safety that determines specific behaviors within a defined operation that are appropriate. JAS evaluates an operation by looking at each activity performed by employees and then identifying all risks that correspond to those activities. JAS provides specific instructions and procedures for completing each of the identified actions appropriately to minimize risks and maximize safety. This analysis also considers a variety of different job components including motion, efficiency based on time, specific movements, and pace. It looks at both normal job conditions as well as examining job activities related to possible emergencies or non-routine conditions, which is when accidents most commonly occur. JAS is often incorporated into safety training programs and operations guides.

Drugs and alcohol

Alcohol, illegal drugs, prescription drugs, and over the counter drugs all have an effect on the human brain. Their effects can include impaired judgment, loss of control of motor skills, sleepiness, slowed reaction time, and altered mental states. Individuals in a work environment using these substances present an increased risk for accident, injury, property loss, or death. Research has indicated that workers who habitually come under the influence to the job missed work 16 times more frequently. Use of alcohol and other substances increases the use of sick leave and statistically increases the likelihood of needing workers compensation payments. Employees who are under the influence of alcohol are four times more likely to be involved in an accident. Use of these substances while at work increases the chance that employees will make costly mistakes, cause an accident, perform lower quality work, or work less efficiently. Most employers offer substance abuse counseling or programs to employees who need it.

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Judgment and emotion

Judgment involves making decisions or determinations based on perceptions, knowledge, and values. When individuals make judgments, they often consider a quantity of information and combine that with what they already know or feel. Forming judgments can be an instant process or take place over a longer period. In situations where snap judgments are required, the outcome is often critical. Having training and knowledge to pull from, helps individuals form more appropriate judgments. Additionally, each individual may react differently under specific conditions. Individual emotions such as fear, anger, and determination influence how risks are perceived and what judgments are formed. This can be beneficial or more dangerous in a crisis.

Biorhythms

Biorhythms are hypothetical cycles that individuals experience that influence their behavior in a number of ways. According to this theory, the body has set cycles of 23, 28, and 33 days that influence all aspects of life including physical strength, emotion, intellect, reasoning, and judgment. This theory would support that an individual's current cycle location influences their behavior in ways that could promote or contradict safety. This theory is only hypothetical and does not have wide scientific support. Risk-taking behaviors are those which frequently place an individual at greater risk for accident, injury, or loss. Some individuals can be identified as risk-takers are often involved in more accidents and exhibit a higher number of absences from work. This comes from learned or acquired behaviors that pose a higher safety risk. Examples of risk-taking behavior outside the workplace include gambling, sky-diving, and habitually speeding. This same level of judgment carries into the workplace.

Hazard control

Most hazards are man-made and result from human error or oversight. Often these hazards are put in place in the very beginning of the design process such as planning buildings, creating production procedures, or developing new equipment. At the planning and design stage common errors include failing to consider environmental influences,

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mathematical miscalculations, inappropriate choices in materials, faulty assumptions, and not factoring in product durability or useful life. People create additional hazards as the process continues in areas such as inefficient scheduling, maintaining equipment and facilities, and operation procedures. Human nature introduces problems with communication, stress, insufficient training, and personality traits into the mix, creating additional hazards.

The underlying principle and main goal of hazard control is to reduce the risks that hazards present. The first step in this process is the ability to identify and locate existing hazards. The next step would be to choose the most appropriate response to the hazard and take action. It is important to analyze how well the chosen action is performing and make adjustments as needed. Prioritizing desired actions in hazard control starts with the most desirable which is eradicating the hazard altogether. If this cannot be accomplished the next steps would be lessening the degree of risk through safety devices, established safety standards, the use of safety equipment, warning labels and devices. Reducing hazards can be accomplished by decreasing the number of accidents or by limiting the impact an accident might have.

Classes of hazards include:

Materials in motion

Within a work environment mass and speed are two very important elements. Equipment, transportation vehicles, and assembly line speeds must be regulated in order to keep control. The movement of materials from one stage of production to another also requires close monitoring. If this flow is too fast, materials might back up and workers might create hazards or increase risks by working too quickly.

Falling loads

Materials that are stacked or elevated pose the risk of falling on people, equipment, or other materials causing injury, damage or death. Measures must be taken to insure all loads are correctly balanced, limits on stacking and lifting are observed, and proper equipment is used in the process.

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Material handling

There are many hazards associated with handling different materials. Often this is from the materials themselves which might be toxic, flammable, or explosive. Other dangers come from the methods used to handle materials including manual lifting or potentially exceeding equipment weight limits.

Reducing hazards

The ideal time to develop safety plans is during the design stage of a new plant, building, or operation. This is financially advantageous is reducing the need for expensive retrofitting of equipment and devices. It also eliminates the need for costly remodeling and construction projects to improve safety. Specific design principles can be incorporated at this stage with safety in mind. Designers should give consideration to possible hazards created by predictable human behavior and develop a plan that protects people from themselves. Some areas that designers should pay close attention to include the placement of safeguards in the process of using, up keeping, and cleaning equipment, with the premise that people will take unnecessary risks. Ergonomic design should be prioritized to create healthy work environments that reduce the risk of illness or injury. This can include air filtration, appropriate desk height and seating, and lighting placement and type. Designers can utilize job safety analysis (JSA) techniques to pinpoint human behaviors that might contribute to safety hazards and compensate accordingly in the planning process.

Types of hazards

Handling materials can present a number of risks including biohazards, flammability, explosive properties, and use of equipment. Lowering the number of times each of these risks is encountered will lower the statistical likelihood of an accident occurring. Planning carefully to insure appropriate equipment is used and potential risks are recognized is a factor in this process as well. Clear communication and in-depth understanding of safety procedures, controls, and emergency responses is critical. Individuals responsible for handling material as well as management involved in decision making should remember the potential cost of an incident when considering the cost of potential handling methods.

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Burns are classified according to how deeply the damage penetrates the skin. If the injury is limited to the epidermis, or outer layer of skin, the burn is identified as first degree. Typical characteristics would include redness and pain as well as a recovery time of approximately five to ten days. The next level is a second degree burn which affects both the epidermis and the dermis, or inner layer of skin. Pain is greater than with a first degree burn and additional symptoms include redness, blisters, blackened or white skin, peeling, and signs of shock such as paleness and cold, clammy skin. This type of burn has a higher risk of infection and takes about 10 days to a month to heal. The most severe burn classification is third degree. This level of burn involves skin destruction as well as possible damage to tissues below the layers of skin. Characteristics include all those of lesser burns as well as leathery appearance, lack of pain from nerve damage, and extreme swelling. Healing takes long periods and usually leaves extensive scarring.

There are a number of potential safety hazards in the use of power vehicles like bulldozers, backhoes, and front end loaders. These hazards include limited visibility, movement of traffic, exceeding load limits, loading procedures, incorrect use or operation of vehicles, and problems with power sources. Most types of powered vehicles have some impediments to visibility while operating. This creates a risk for collision with other vehicles, objects, or people. Traffic and the movement of other vehicles create hazards for these vehicles as well. If careful attention is not paid to observing load limits and correctly placing loads to consider movement, gravity, and distribution, damage can be done to vehicles, spills can occur, and falling loads can hurt people or damage property. Human error in the operation of the vehicle can also result in property damage, injury, or even death. Fuel sources such as propane and diesel are very flammable and present an additional hazard in an accident. Vehicles with closed cabs are can place operators at risk for carbon monoxide poisoning from vehicle exhaust.

Tripping results from interference with the movement of a person's foot while stepping. A short interruption usually results in stumbling, while a longer one can cause a fall. Falling is the cause of about 20% of unintended deaths. Slipping and falling, cause more deaths in

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the home than any other factors. Hazards that can contribute to tripping include any uneven surface that people walk across such as loose flooring or damaged concrete and out of place objects in a traffic path. Since people's normal line of sight does not include their feet, objects and floor hazards often go unobserved. Other factors that contribute to these hazards are camouflaged colors, low lighting, blending textures, and glare which obscure the area.

In order to reduce tripping hazards, walkways should be kept free from items such as pallets, file drawers, tools, lumber, and small equipment. Waste and trash should be picked up regularly. Changes in floor level should be eliminated or decreased. When flooring does change, it should be clearly marked in a different color from the floor surface. In addition, warning signs should be used to advise of changing levels and lighting must be sufficient to show changes. However, overly bright lighting or types of lighting that produce a glare should not be used. Textured patterns should not be used in flooring since they can hide elevation changes. It is important to conduct frequent inspections of flooring and level changes, maintaining and repairing damage as needed. Inspections should look for damage to floorboards, flooring materials, and loose screws or nails.

A slip is when one or both of a person's feet skid on a surface or lose contact possibly resulting in an unplanned fall. Slips can be responsible for muscle strains and sprains and injuries to joints. Contact with the ground resulting from a fall can result in fractures, dislocations, and other bodily trauma. Resistance is determined by the impact point of a person's foot and a surface. Slips commonly happen when resistance between the floor and people's feet is inadequate or the level of resistance is suddenly altered. Other factors include a person's walking style, motion, stride, or type of activity. Resistance is also impacted by friction from movement and friction that exists without movement. Common conditions that change resistance are the presence of oily, greasy, wet, or unexpectedly dry surface materials. Unexpected and out of place materials and the type of surface texture can also cause slips.

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Multiple hazards exist when moving materials laterally. These include the possibility of materials falling while raised, resulting in injury or property damage, structural failure due to excessive loads, and contact with electrical and telephone lines. Some controls that can be used to reduce these hazards include taking steps to carefully plan the move and set up equipment correctly. Conditions at the job site should be carefully checked such as finding level surfaces, soil conditions, and presence of overhead lines. Any equipment being used should have easily identifiable load limits and proper components for safety. This might include outriggers to anchor equipment for stability. Any individuals operating the equipment should be fully trained in potential risks, malfunctions, and other problems that occur. Such training should include how to respond to accidents and other dangerous situations.

A variety of different conveyor types are commonly used to move materials including roller, bucket, belt, chain, and overhead models. Some conveyors use manpower for movement, others use the force of gravity, and many are mechanized. Some of the hazards associated with the use of conveyors are items falling, malfunction of the devices or overall structure holding up the conveyor, and the risk of things such as body parts, hair, or clothing getting snagged by moving parts. Another risk is the pinch points that can often be found allowing body parts such as fingers to be trapped between two immoveable parts. Controlling these hazards can include the use of overhead guards to keep materials from falling onto people or property, protection devices on all moving components including emergency shut off features, and reduced speed functions to reduce risks during service and maintenance. Additional warning devices including lights, signs, and audio signals such as sirens and beeping should be installed to draw attention to potential hazards that cannot otherwise be protected against.

Sound hazards

The following lists the different ways sound is measured:

- Sound amplitude – is the force of sound waves measured according to pressure and distance and sensed as loudness

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- Sound power – is the amount of energy produced by the cause of a sound measured in watts (W)
- Sound pressure – are alterations or fluctuations of air pressure caused by the introduction of sound waves commonly measured in Pascals (Pa)
- Sound intensity – measures the movement of sound using speed and distance as joules per square meter per second and is commonly referred to as sound magnitude
- Decibels (dB) – are actually ratios between two amounts but are more commonly recognized as the unit of measure for sound with higher numbers indicating louder sound and lower numbers indicating softer sound

Sound refers to the sending and receiving of waves, most commonly through the air. Our ability to hear allows us to receive sounds carried by these waves. One of the classifications of sound is frequency which measures the number of waves and vibrations perceived by hearing. Octaves break the range of audible sounds into smaller sections based on frequency. Each increase in octave indicates that the frequency is twice that of the previous octave. Sound distribution is pressure that is reduced as distance is increased from the source of the sound. When distributed in an open environment, sound moves from the source in a spherical pattern. Closed spaces cause sound to distribute in an uneven pattern. Materials, walls, surfaces, and openings catch and alter the sound as it moves.

The human ear has three primary components: the inner, middle, and external. The part that is visible is the external ear. Its main function is to direct sound into the ear canal using skin covered cartilage called the pinna. It also magnifies incoming sounds by about 23 decibels. The middle ear conducts sound through an air-filled area known as the tympanic membrane before reaching the inner ear. At this point sound waves have become sound energy. Within the inner ear is an area filled with fluid known as the cochlea which is separating into two chambers. Sound moves from one chamber to the next working with the pressure created by the sound. Within the cochlea are hair cells which recognize

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frequencies. Those on the top pick up low frequencies while the bottom cells focus on high frequencies.

Most effects of noise on humans are considered negative and often cause some degree of damage or harm. The most common of these is hearing loss. Hearing loss can be caused by infections of the inner ear which result in permanent scar tissue, injury to the eardrum, and commonly by excessive exposure to noise or exposure to higher decibels of noise. Each person is affected differently by noise exposure with amplitude, frequencies, individual predisposition, and duration being significant factors. Hearing loss can result in missing out on audible cues that indicate hazards and can cause the brain to interpret sounds differently. Noise can also contribute to accidents by interfering with reception of other sounds and creating distracting environments. Noise can also interfere with learning and processing information which can profoundly impact education in schools as well as quality and quantity of job performance in work environments.

OSHA guidelines establish the following formula for calculating time-weighted average (TWAN) for permissible noise levels during an 8 hour day:

$$TWAN = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n}$$

If the amount of the time-weighted average is larger than 1.0 than the rate of noise exposure is above OSHA guidelines. The following table can be used to determine exposure:

Noise Level (dBA)[1]	Duration (hr)
110	0.25
100	0.5
90	1.5

Conducting a survey to measure noise levels can help assess if people are being subjected to excessive noise levels beyond standard and can also determine if certain conditions are

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present that could lead to excessive sound exposure. A tool commonly used in this type of assessment is a noise dosimeter which measures exposure to hazardous conditions over a period of time. Surveys often involve the use of this tool during the duration of a normal work day and are placed with an individual within his normal work environment. The instrument continuously inputs noise levels giving a reading at the end of the work day that indicates an individual's total noise exposure. Surveys can also be conducted within a variety of areas within a work environment to pinpoint problem locations.

Hazardous materials spills

In identifying hazardous materials spills, an immediate red flag would be a situation involving an overturned or damaged transportation device labeled by the Department of Transportation as containing hazardous materials. Within a fixed work environment such as a factory or construction site, containers holding hazardous materials should also be labeled and easily identified if spilled. Extreme caution should be used and immediate action taken if the spilled materials produce a distinct smell, emit a smoke or visible vapor, or are observed to be bubbling. These signs can indicate that a dangerous chemical reaction is occurring. If an individual observes these conditions, quick action should be taken to remove people from the immediate vicinity of the spill. It is important that this relocation place people as far as possible from the spill and avoid downhill and downwind movement to reduce the chance of injury. The appropriate emergency and regulatory authorities should be contacted immediately for evaluation, containment, and cleanup.

When approaching a situation in which hazardous materials have spilled, three main steps should be followed. The first and most important step is safety. Every hazardous material spill should be treated as toxic until otherwise determined. Individuals working with hazardous materials should be trained to stay an appropriate distance from any known spills, remembering that these materials can produce chemical reactions that do not require physical contact to be deadly. While contamination can occur by drinking or eating hazardous materials as well as contact with skin or eyes, hazardous materials can also pass into the human body simply through breathing vapors or fumes. Safety means that all

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individuals located near the spill are relocated to a safe distance. The next step is isolation. To the extent possible, the location of the spill should be contained. This might mean shutting single rooms or entire buildings. The third step is notification. The individual who discovers the spill should follow all standard procedures for notification including immediately contacting his supervisor and the appropriate emergency agencies.

Contaminants

Particulate contaminants

Particulate contaminants cover dust, fumes, smoke, aerosols, and mists and can include materials in either a solid or liquid form. They are further divided according to shape and size, varying greatly with some as small as one micron. Particulate contaminants can be produced in a number of ways including mixing, grinding, crushing, compression of vapor, burning of materials, and condensing gases.

Gases

Gases are formed from liquid materials that are heated to a specified temperature or compressed to a certain degree. Gases that are released through certain individual and industrial activities are considered contaminants if their effect is in any way toxic or hazardous to plants, animals, humans, or the environment. Gases can be released in a number of ways including industrial byproducts, automobile exhaust, and home grilling.

Acute exposure refers to contact with some substance over a very short period of time. This could be a small as a few seconds or as long as a couple weeks. Chronic exposure refers to contact with a substance over an extended period of time, usually in excess of a year. The results of different exposures can vary significantly with some materials producing an immediate effect while other effects do not become visible for years. The level of damage from different materials and periods of exposure also varies significantly. The time between exposure and the appearance of an effect is known as the latency period and can be as long as 40 years.

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Effects from exposure can be categorized as local or systemic. Local effects can result from a single exposure and often are immediately visible. The effect is usually contained to a limited area such as a burn, a respiratory inflammation, or loss of vision. Systemic effects result from the introduction of substances into the body through means such as inhalation, absorption, or ingestion. Systemic effects are seen in multiple body systems and can include kidney failure, liver disease, cancer, and neurological disorders.

Human reaction to chemical exposure can differ considerably. The duration and severity of the effect is significantly impacted by the nature of the specific chemical, duration and speed of exposure, and the method of exposure. The effect of chemicals also varies for each part of the body. The rate at which symptoms of exposure appear can also vary by individual. Some individual factors that influence this are weight, gender, allergies and existing conditions, and overall health. Exposure to certain chemicals can alter a person's behavior. Although each person reacts differently, certain chemicals do produce common reactions. For example lead toxicity can produce memory loss, sluggish demeanor, and hallucinations. Common symptoms of chemical exposure such as nausea and headaches can easily be mistaken for other disorders and overlooked. Detecting chemical exposure is made further difficult by the frequently varying reactions of two people with the same level of exposure.

Toxicity is a measurement of how toxic or poisonous a particular substance or object is. Information on the toxicity of different materials is gathered in several ways. One consideration is studying the effect of different levels of a particular substance as well as different levels and methods of exposure. Researchers conduct experiments on animals and people, noting a number of different factors. A threshold level is established at the point when symptoms are first noticeable. The majority of testing is done on animals with smaller, controlled studies involving people. Results are extrapolated from animal testing to apply to people. This helps develop baseline knowledge about human reactions. A concern in establishing toxicity is the effects that have longer latency periods. Testing at

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this level is costly and excessively time consuming is infrequently conducted. Much of the animal testing utilizes much higher exposure rates in lieu of longer periods.

Toxicology is the study of the impact of toxicity. The main reference source for information on toxicology is Dangerous Properties of Industrial Materials. The publication includes toxicity information on more than 18,000 materials. OSHA mandates that manufacturers and distributors of potentially hazardous substances supply material safety data sheets (MSDS) to all recipients detailing information about chemical makeup, toxicity, elements, and effects. Toxicity is rated based on severity with 3 being the highest level of hazard. Level 3 identification is further divided into four categories of exposure: chronic local, chronic systemic, acute local, and acute systemic. Acute local exposure involves materials that can cause life endangering conditions or death with a single exposure involving the eyes, skin, or mucous membranes. Acute systemic exposure involves materials that can cause life endangering conditions or death with a single exposure through inhalation, absorption, or ingestion into the body.

The concentration of toxic substances in the air can be determined by evaluated gather air samples. Evaluation can include a number of different approaches which often vary based on the type of substance or the state of the matter. Some approaches consider a worker's exposure and determine if it is within established safe limits. Other techniques measure for present contaminants and determine the actual concentration in the air during a specified period. Measuring air toxicity utilizes several devises such as automatic sensors which conduct take continuous reading and alarm systems that advice workers to move out of an area where air levels have become unsafe. Some types of equipment are personally carried or worn by workers on the job while others are always present in the work environment. Organizations can follow the guidelines put out by agencies such as OSHA and NIOSH on how to test for specific contaminants. ASTM also assists organizations with standard testing equipment and additional evaluation and air sampling methods.

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Chronic local toxicity

In measuring toxicity levels, chronic local and systemic toxicity is designated as a 3, which is the highest risk. Chronic refers to long term exposure that can last for as short as a few days or as long as many years, perhaps a person's entire work life. This type of exposure can lead to permanent injuries that cannot be undone. Chronic local toxicity is direct exposure through the skin, eyes, or other mucous membranes which over a period of time can cause injuries or damage which will never heal as well as permanent disabilities. LD refers to lethal dose and LC means lethal concentration in the air. LD_{50} refers to a toxicity level that leads to death in 50% of individuals who are exposed to the substance. TCL and TDL indicated the lowest lethal concentration and dose that is known.

Pneumoconiosis is an inclusive label for a variety of diseases of the lungs caused by the inhalation of different dusts or particulates. More specific names are given to different cases of this disorder to indicate the substance responsible.

- Asbestosis – industrial or occupation exposure to asbestos fibers
- Silicosis – silica dust from industrial stone work such as sandblasting or mining
- Berylliosis – beryllium fragments
- Byssinosis - agricultural or industrial cotton dust
- Siderosis – iron oxide from mining or welding
- Kaolinosis – occupation exposure to china clay dust
- Bauxite pneumoconiosis – exposure to vapors, gases, or smoke in metal extraction involving bauxite

Rating system for toxic substances:

A number of different factors are considered when rating toxic substances. Toxicity ratings are published using a scale of 1-6 or 1-10, depending on the preference of the evaluator. The following elements are considered in rating toxicity:

- Time concentration factors (Ct) – are a standard measure of toxic gases which are inhaled

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- Dosages (D) – are a standard measure of liquid or solid toxins ingested, absorbed, or inhaled
- I or L – are used to indicated an exposure level that is debilitating or deadly
- Threshold limit values (TLV) – measures the amount of exposure to a particular toxin that an individual can sustain during an average working lifetime without a negative impact
- Emergency Exposure Limits (EEL) – measures the amount of time that an individual can stay in an environment that contains identified amounts of a toxic gas without negative impact

The most common delivery method of toxic substances is through the mouth. Another toxin intake point is the skin through cuts, breaks in skin, injuries, or injections. Toxins in the form of gas or vapors are inhaled through the nose and mouth into the lungs. Certain types of toxins, known as asphyxiates, stop oxygen from been taken into the blood and cause a shortage of oxygen. Oxygen deprivation can lead to organs shutting down and interference with normal function. Toxins called irritants cause irritation and swelling and the exposure site. Different areas of the body have different levels of vulnerability to toxins. The most susceptible are the eyes, mouth, and mucous membranes. Some toxins cause damage to specific organs or body systems and many toxins directly affect the liver because of its filtering function.

When evaluating an exposure the key factors to consider are agent, attributes, and length of exposure. The first priority is to determine what agent or hazardous substance is involved in the exposure. This will require different methods depending on the state of the matter. For example, ultraviolet radiation requires measurement in wavelengths. Another factor to consider is the attributes of the environment such as temperature, air speed, light, and other materials that are present. Attributes of the agent itself are also important such as concentration, mixture with other materials, and state. The third key item is the length of the exposure measured in time. This can be a matter of seconds or as long as years. Exposure time must be factored with strength of the materials to evaluate the exposure.

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Concentrations of contaminants

In a fixed environment, contaminants can be gradually introduced over a period of time. If that environment has clean air at first and only a set amount of fresh air is introduced over time, the level of contaminants can grow over a period of time. This relationship can be explained by the following formula:

$$\frac{G - (Q/K)\,C}{G} = -\frac{(Q/K)\,t}{V}$$

In this formula C=concentration of gas, G=how fast the contaminant is being introduced, Q=how fast fresh air is being circulated, K=a safety factor that considers the combining of contaminants with surrounding air, and V=the volume of the environment.

Smoke tubes are devices that distribute smoke or viewable powder in order to indicate movement of air flow.

Three classes of controls for protecting people from exposure to hazardous materials in the workplace:

Engineering controls

These elements are introduced at the operations design level and can include alterations or material substitution to eliminate or reduce the use of hazardous substances. Other engineering options include creating barriers to separate workers from hazardous substances, securing hazardous substances, and designing and installing adequate ventilation.

Work practices and administrative controls

These elements provide greater protections by establishing procedures and instructing personnel in areas such as handling and moving hazardous substances, cleaning, maintenance, and personal habits. Workers should be trained in the potential hazards of not following established procedures.

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Personal protective equipment

If modifications cannot be implemented through engineering, work practices, or administrative controls to eliminate hazards, workers should use protective devices and clothing to add protection. This can include goggles, respiratory masks, chemical and flame resistant clothing, and eye shields.

Sampling methods

Sampling methods for gases and vapors can be categorized as long term or short term. While long term sampling involves sample collection and analysis over an extended period, short term sampling looks at immediate conditions. Acquiring a short term sample is referred to as a grab sample and is accomplished by sucking air into a completely empty, container with no contaminants. A squeeze bulb or manual bulb can be used in the process. Glass detection tubes can be utilized as well to check for specific contaminants in the air. Each tube contains a specific substance designed to react with certain materials and produce an informative color change. The glass tubes are secured until ready for air exposure. This method, known as colorimetry, can provide fast answers about the safety of an environment's air. If a longer evaluation period is desired, more complex equipment is usually indicated. Long term sampling can involve the use of oxygen meters, gas chromatographs, and combustible gas meters.

Each contaminant requires different identification techniques based on the nature of the material, its form, and the sampling technique utilized. The following are different methods that might be used:

- Colorimetric techniques use reactive substances that produce a color change in the presences of the indicated contaminant with the intensity of color indicated the quantity of the contaminant.
- Ion exchange takes samples and moves them through calibrated columns filled with a substance that extracts contaminants for identification.
- Gravimetric techniques operate by weighing samples that are gathered.

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- Volumetric techniques consider the reaction that is produced when a sample is mixed with a specific volume of an indicated agent.
- Gas chromatography determines how long it takes for a substance to move through as specific material designed for detection purposes.
- Spectroscopy involves the creation of a spectrum which produces a unique identifier if certain contaminants are present by using a carbon arc, electron beam, or infrared radiation.

Particulates include matter in both solid and liquid state. Common devices used to collect samples include impactors, filtration, separators, and impingers. The choice of sampling devices is dictated by the desired data to be gathered. Often filtration techniques are used to capture particles. An impactor utilizes air flow changes to collect particulates which cannot reverse their course due to size. An impinger forces air through a tight space causing the air to collide with the surface of the collection device. The intended surface traps the particulates. Particulates are captured and can be evaluated. A centrifugal separator spins air which causes particulates to relocate away from the air space as a result of the weight difference. This allows easy collection outside of the central area.

Acceleration hazards

Acceleration occurs when an object or substance in motion increases its rate of speed. Acceleration can create hazards that contribute to a number of accidents, injuries, or damage. A frequently occurring injury caused by acceleration is whiplash. Acceleration can also result in collisions or falling of objects, people, or vehicles. Objects that impact the human skull at 50 lbs of acceleration will cause bone to crack or shatter. This means that an item weighing 5 lbs can fracture a person's skull if dropped on them from just 10 feet. Acceleration can cause materials, especially liquids to spill from containers. This creates an obvious hazard if those materials are toxic or corrosive. Negative acceleration or deceleration is also dangerous. This refers to a reduction in speed or abrupt interruption in motion. Whiplash can also result from deceleration and sudden stops in the movement of materials or liquids can be hazardous.

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Atmospheric and pressure hazards

The impact of oxygen's partial atmospheric pressure on the human body is to dictate the capability of the blood to transport oxygen to all parts. The most important component in this is hemoglobin in the red blood cells which actually moves the oxygen. Hemoglobin also carries away carbon dioxide which is eventually turned back out into the atmosphere and the cycle starts again with oxygen. In the ideal environment such as sea level elevation, 97% of the red blood cells are actively engaged in this process. As a person moves to higher elevations, atmospheric pressure decreases as does the partial pressure of the oxygen in the atmosphere. This change decreases the number of red blood cells that can connect with oxygen, which decreases the amount of oxygen reaching the body's cells. For a limited time the body can work around this by altering breathing to incorporate deeper and faster patterns as well as increasing the heart rate. If an individual remains in a low pressure environment for an extended time, the body begins to make more red blood cells to compensate for the oxygen reduction.

Dalton's law of partial pressure: John Dalton proposed his law of partial pressure based on observations of gas mixtures. He determined that the total pressure of a mix of gases was equal to the total of partial pressure that each gas in the mix presented individually. Dalton's model is based on ideal conditions, which do not always exist. Pressures are affected by elevation, with locations below sea level having the highest pressure, dropping as an individual moves above sea level. This affects both total and partial pressures. For example, in Earth's atmosphere the two main gases are oxygen and nitrogen. Oxygen makes up about 21%, so it exerts 21% of the atmosphere's total pressure. Nitrogen makes up about 78%, so it exerts 78% of the atmosphere's total pressure. As altitude increases, total atmospheric pressure decreases which means each partial pressure decreases respectively. However, the individual gases still retain their percentage makeup of the total.

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Hypoxia

Hypoxia is a state of bodily deprivation of oxygen that can be metabolized. If less oxygen is moved through the body cell metabolism is changed. Oxygen deprivation can be viewed through altitude, partial pressure, and red blood cell saturation. An early indicator of hypoxia is loss of night vision, which is prominent in higher altitudes. Other indicators of increasing hypoxia are loss of memory, impaired judgment, sleepiness, unexplained elevated mood, loss of coordination, and loss of consciousness. Ultimately hypoxia can lead to death. Quick descents from high altitudes to elevations closer to sea level, such as in an airplane, create pressure changes that produce hypoxia. This can be experienced with decreased middle ear venting and facial pain resulting from blocked sinus cavities.

High altitude dangers

High pressure environments require monitored atmospheric conditions for appropriate oxygen partial pressures. Additionally, contaminants and toxins produced by engines and equipment must be purged from the breathing gases. Inert gases can be used in place of undesirable elements such as nitrogen, which must be removed to prevent nitrogen narcosis. Decompression sickness can be reduced by avoiding excessive subjection to high pressure and by exercising greater control over the rate of decompression. Use of reliable and tested resources on pressure exposure can reduce risks. The U.S. Navy has produced diving tables considered to be the best source on appropriate subjection times to various pressures as well as established procedures for decompression. Another source is the diving tables published by OSHA that offer various scenarios for exposure with different pressure levels, exposure times, and steps of decompression.

High pressure containers

Different products and industrial and manufacturing procedures necessitate the use of a number of different high pressure containers. These include aerosol cans, boilers, water heaters, tanks, and propane and other gas cylinders. Some equipment and materials such as pipes can become pressurized under certain conditions like testing for leaks, fires, or

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explosions. This creates additional hazards. The following are specific hazards common to high pressure containers:

- Chemical breakdown of metal or other types of damage can result in weakness in a container
- Container pressure can rise above intended levels leading to container failure or leaking materials
- Additional oxygen present in many pressurized containers can lead to an increased risk of fire

Controls that eliminate or reduce the dangers of high pressure containers:

Limit pressures

Container pressures should be established at the lowest needed pressure for the container to work as needed. All pressure needed in a procedure should be carefully controlled using equipment intended to prevent over-pressurization from occurring.

Avoid pressure buildup

Pressure in containers can be increased by exposure to intense heat or sunlight. Containers should be used and stored in areas that reduce this risk.

Controlled release

Pressurized materials should be released under controlled conditions with careful attention given to the location and direction of release. Harmful substances and steam release must be directed away from people and other materials and conducted in an environment where the fewest individuals possible are exposed to risk.

Train workers

Employers must educate workers about hazards associated with pressurized containers and provide training on procedures to protect people and property.

Operating principles

Overpressure equipment can be used with materials in all states of matter. These devices vary in the amount of supervision and maintenance needed. The American Society of Mechanical Engineers (ASME) Boiler and Pressure Bessel Code is a reliable source for the

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implementation and use of these devices. The following are examples of overpressure devices:

- Safety valves are engaged when upward pressure exceeds a certain level that has been established. This causes the valve to open allowing release of pressure.
- Relief valves are designed to open a certain amount in relation to the quantity of overpressure that is present. Overpressure is determined based on certain levels that have been established.
- Safety relief valves are engaged when they sense a pressure increase in relation to a level that has been pre-established.
- Frangible discs are thin metal pieces installed between protruding edges within pipes. They are designed to burst if pressure exceeds the levels that have been established. This allows pressure to escape. These discs can vary greatly in size.

Pressure and temperature

The physics principle that defines the association between air pressure and temperature is commonly referred to as Boyles-Charles Law. This principle identifies that at an unchanging temperature, volume and pressure are inversely proportionate. This principle establishes the following formula: $P_1 \times V_1/T = P_2 \times V_2/T_2$. In this formula P=absolute pressure, V=volume of pressure, and T=absolute temperature. This law identifies a directly proportionate relationship between volume and pressure and temperature. In practical application this means that a pressurized container exposed to heat will result in increased volume of the pressurized material as well as increased pressure per square inch.

Henry's law

According to Henry's law when gases are under pressure they can change into a liquid state. If the pressure around this liquid is reduced, gas is released creating bubbles. This law is easily seen in carbonated, canned soda. In an atmosphere of high or low pressure, individuals will not be as able to take oxygen into the blood. This is because oxygen is a gas which will turn into a liquid much more slowly due to lower pressure surrounding it. This can result in oxygen deprivation or hypoxia. Ultimately hypoxia can cause confusion,

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impaired abilities, loss of consciousness, and death. In high altitude or low pressure environments, oxygen levels in the breathable air mixture must be altered to allow for the changes in absorption. Increased oxygen also contributes to a greater risk of fires.

Hydraulics and water/air lines

Compressed air, hydraulic lines, water hoses, fuel injection devices, pneumatic and hydraulic tools, and spraying equipment are all examples of devices that utilize pressurized matter in both liquid and gas states. These types of devices present a number of dangers including unattended or out of control lines thrashing around, tissue damage from materials being forced against skin, eyes, or mucous membranes, and actual injection of materials below the skin due to force of pressure. The force of pressure can cause the introduction of hazardous materials to the body as well as causing surface injuries such as cuts, welts, bruising, or abrasions. This type of contact can be toxic producing organ damage, systemic illness, and advanced toxicity which results in amputation or even death.

Compressed air and fluids

Environmental pressures that are higher than those at sea level are found in a number of occupational and even recreational situations. Common examples are construction work, underwater diving, and aircraft. When addressing breathing conditions for underwater diving, surface air sent down to a diver must be controlled for oxygen level. This level must be decreased as the diver descends below 65 feet. Nitrogen narcosis is a hazard that can be reduced by using other inert gases such as helium instead of nitrogen. This is often safer at higher pressures and can reduce effects such as sleepiness, weakness, and unexplained mood elevation. Alternate inert gases also present risks to be considered. For example, helium can cause difficulty with communication and movement of heat. Speech is especially problematic due to the higher frequency that is produced with helium as is decreasing body heat that is better maintained by nitrogen.

According to Dalton's Law of Partial Pressures, the total pressure of a gaseous mixture is equal to the sum of the individual pressure of each of the gases in the mixture. This is

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shown in the following formula: $P_{total} = P_a + P_b + P_c$. Using this formula, the relationship of individual gases and their pressures can be determined. Consider the following mathematical example:

If the total pressure of a three gas mixture is 60 kilopascals, and P_a = 25 kilopascals, and P_b = 23 kilopascals, what is the partial pressure of P_c?

$P_{total} = P_a + P_b + P_c$

$P_c = P_{total} - P_a - P_b$

P_c = 60-25-23

P_c = 12 kilopascals

Light hazards

The power of any given light source is indicated by candlepower or candela. The amount of actual light produced by a source is indicated in lumens (lm). Luminance refers to the light that is bounced off of a surface and is measured in foot lamberts. The nature of light results in distribution in multiple directions as well as uneven distribution. The strength of light decreases as it moves further from its original source. The reduction of light strength is proportionate to the square of the distance it has traveled. Light moving through certain spaces can be referred to as flux which is measured in lumens or luminous flux. Illumination is used to describe the presence of light on a surface and is indicated in foot-candles. The nature of the surface from which light is bounced is referred to as reflectance which is expressed in percent.

Fires

Fire suppression systems that rely on materials other than water are preferred in certain environments. These types of systems often use carbon dioxide to remove oxygen from the air and remove fuel from the fire. Fires can be prevented or extinguished using the following:

- Periodically remove inert gases from equipment

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- Use natural drafts to circulate fresh air and reduce the amount of hazardous or flammable materials present in the air
- Installation and maintenance of a well designed fire suppression system using carbon dioxide
- Use of fail-safe devices that disengage and power off electrical components if temperatures exceed certain pre-set limits
- Dry chemicals can be used in suppressing electrical fires or fires fueled by hazardous liquids
- Fire suppression foam can be used under certain conditions to keep flammable liquids from becoming gas and has the advantage of expanding to reach tight places

Transportation hazards

Railroads present a number of hazards including derailment resulting in fire, explosion, environmental contamination, inappropriate transportation of hazardous materials, and accidents resulting from collisions with vehicles at crossings. Safety aboard railcars has been improved through the use of grab bars and ladders to facilitate climbing. Safety engineers are constantly improving warning devices at crossings. Tankers have been designed with insulation that keeps temperatures from rising to unsafe levels. Companies that ship hazardous materials must insure that containers used are safe and appropriate for the material, packing methods are appropriate, transportation methods used are safe, and any storage in route is within safety guidelines for the material.

The federal government passed the Transportation Safety Act in 1974 to address dangers associated with moving hazardous materials. This law regulates packaging, labeling, and moving hazardous materials and assigns penalties to companies or individuals who violate its mandates. This act organizes hazardous materials into different categories including radioactive, flammable, corrosive, combustible, and biological hazards. Risks are reduced by specifically designing safety guidelines for each category. Controls include identifying specific materials and associated hazards, establishing guidelines for labeling, placing limits on quantity or size of materials transported, monitoring movement of materials,

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mandating training, banning movement of some materials, and specifying packaging and container materials. The movement of hazardous materials is overseen by the Department of Transportation which publishes data on hazardous materials with daily updates on the Federal Register. Companies and individuals who move hazardous materials bear responsibility for knowing and complying with these guidelines and mandates.

Media regarding transportation of hazardous materials is published by a number of government agencies and private organizations including the National Highway Traffic Safety Administration, the Federal Motor Vehicle Safety Standards (FMVSS), the Society of Automotive Engineers (SAE), the Department of Transportation (DOT), and the Urban Mass Transportation Administration. All entities produce materials that establish safety standards and guidelines designed to reduce or control hazards associated with moving certain materials. These include identifying hazards through labeling, manifests, specific coded design of packaging using colors and symbols, established routes, and education for individuals involved. Additionally, federal agencies such as DOT set up specific rules related to packaging and containers for particular materials. These rules include both mandates on what can be shipped and how and also the identification procedures to be used.

A valuable reference tool for rigging loads is *The Handbook of Rigging*. It offers guidelines for choosing, utilizing, maintaining, and examining materials used in rigging. This publication details items of importance to check when rigging loads. Common failure types in rigging materials are noted such as broken fiber or wires as well as instructions for detecting them. This media tool also provides charts that give guidelines for rigging factors such as weight and balance, safety factors that should be calculated, load limits, and engineering specifications. Use of data in the book such as charts and tables can reduce the risks associated with improper rigging.

Accidents and injuries commonly result from mistakes in the movement and handling of dangerous materials. Labeling all materials properly and generating accurate and detailed

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shipping manifests allows individuals involved in these activities to take proper precautions. Labeling should include identification of the materials as well as proper transportation and handling instructions. Federal regulatory agencies such as DOT mandate appropriate warning signage on all transportation vehicles such as trucks and trains. Hazardous materials shipments must also be tracked with a specific assigned number that can pull up all related data such as material type, quantity, and known hazards. Labeling on a container as well as shipment tracking allows faster response in case of emergencies.

Effective communication is one strategy for lessening the risks of moving hazardous materials. Common tools to facilitate this communication include incident reports and proper training for individuals involved in transporting hazardous substances. Informing appropriate supervisors and regulatory authorities of all non-routine incidents and accidents is important in limiting the negative impact of people and property. For example, the Department of Transportation should be informed of any unintended dispersal of dangerous substances during transport as well as any accidents, illness, or injuries related to moving these substances. All individuals involved in moving hazardous substances should be properly trained in risks, procedures, and emergency response. This includes even individuals with only incidental contact and those with no contact, but supervision over transportation decisions.

Structural and dynamic failure

Individual components, products, materials, and entire structures are at risk from a variety forces and stresses such as torque, shearing, compression, and tension. Dynamic failures are those that can cause failing hazards from material fatigue or breakdown or from impact. Descriptions of structural or dynamic failure often indicated the type of force that contributed. A material's toughness refers to how well it endures an impact load. If loads are constantly changing, material characteristics are also affected increasing the risk of failure. Instability can also lead to dynamic failure and is related to actual objects and their placement rather than the materials themselves. An example of this is falling materials

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caused by an imbalanced load or materials placement. Other elements that influence the different types of force and contribute to failure include friction, gravity, and inability of materials to move.

Structure failure can occur in several different ways. These different modes are characterized as follows:

Design errors - Engineers and designers sometimes make incorrect calculations or inaccurate assumptions about materials, force, load, human impact, and other factors leading to structural failure. Errors in design can result from failure to correctly assess all elements of structure construction.

Faulty materials - Materials might be inappropriate for the structure when initially used or might lead to structural failure over time due to breakdown or characteristic changes from movement or the application of force. Factors that can influence material failure and lead to structural failure include weather, radiation, nature, and vibration or friction.

Physical damage - Structural failure can result from unintended situations or conditions. These events themselves can cause failure or movement of other materials or components during this event can lead to load shifting. Examples might include storm damage, fire, or even another object such as a car or plane colliding with the structure.

Overloading or inadequate support - If a component of the structure or objects or materials within the structure are not provided adequate load bearing support, structural failure can occur quickly or even over an extended period of time.

Structure failure can occur in several different ways. These different modes are characterized as follows:

Faulty workmanship

The human element in structure construction can only be assumed and predicted, not known for sure. Poor judgment, decision making, and lack of caution can all contribute to structural failure. This sometimes results from inadequate training, inexperience, lack of knowledge, unclear or poorly designed procedures, and poor communication. This can be attributed to supervisors, individual workers, or both.

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Poor maintenance, usage, and inspection

Many structures and their individual components are dependent on regular maintenance and inspections to maximize safety. Failure to adhere to these steps can ultimately lead to structural failure. This includes updating and replacing individual components that wear out or breakdown to exposure, damage, or normal use. Additionally, materials, structures, and their individual components have an intended level and pattern of use. Usage that exceeds the design limits can lead to structural failure.

Shelving hazards

When attached shelves to a wall, there are a number of potential modes in which these two elements can fail. It is important that designers consider the potential weaknesses and ways of failure when developing products and systems. When shelves are installed on a wall using brackets and screws, failure can result from screw malfunction or shearing at the wall, wall surface or subsurface materials not bearing weight as intended, or stripping of screw threads. Failure can result from installers using inappropriate materials such as attaching screws into plaster without anchors or from using screws that are too short to properly anchor the shelf in the walls. Additionally, the placement of materials and objects on a shelf must conform to the design indicated weight limit or failure can occur.

Soil hazards

Structural stability and safety is dependent on the use of sound engineering principles including adequate analysis and consideration of soil conditions and properties. This should include the advice of those who specialize in the impact of soil on structural integrity such as metallurgists, foundation engineers, and architects. The following classifying soil properties should be considered:

- Weight – is impacted by the amount of moisture present; dry weight is solid material measured in volume
- Density – is the solidity or thickness of soil which is magnified as soil settles and reduced by digging and movement of soil

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- Resistance or friction – is determined by the different forces that are applied to the soil
- Cohesiveness – is how well the soil components adhere to each other under different conditions
- Volume – is the measurement of soil present in a defined area; is affected by moisture content decreasing with loss of moisture and increasing with additional moisture

The load of a structure is ultimately placed onto the soil. To prevent structural problems or failure, the weight-bearing ability of soil supporting the structure must be considered. Foundation footings and their placement in the soil are also important and must be designed to support not only the structure, but its contents as well. A structure often requires the use of piles or underground columns. The number, depth, and placement of these piles must be determined based on the structural characteristics and the soil conditions including friction and adhesion which influence the transference of weight to the soil. Failure to carefully consider these conditions can lead to structure failure, damage, collapse, injury, death, and other losses. A specific type of structural element that is dependent on soil conditions is a retaining wall. Soil places pressure on the wall intended to contain it. Soil conditions influence the size and materials used in a retaining wall. Its failure can compromise the structure it is intended to protect.

Explosions

There are a variety of controls that can be implemented to prevent or reduce explosions as well as limit the damage or injury that can occur with an explosion. One way to do this is to consider the use, storage, and placement of combustible materials. The amount of combustible materials in a workplace must be limited to that absolutely necessary for operations. Additional quantities of these materials must be stored separately, in limited quantities. Both OSHA and NFPA regulate the storage and placement of combustible materials including limiting quantities. For larger storage placement, the location must be isolated to minimize loss of life or property in an explosion. Storage and placement areas

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for combustible materials should be frequently cleaned to reduce dust build-up which increases the likelihood of explosions. Safety devices like traps and collectors should be installed to reduce the accumulation of flammable materials in lines. Lines transporting these materials should be cleaned regularly. Under conditions where combustible materials are present, oxygen levels should be kept as low as possible to reduce fire risks. This can involve using inert gases in place of oxygen.

Accidental engagement of controls

Accidental engagement of controls can result in accidents, injuries, and costly damage. Some commonly used techniques to prevent accidental engagement include:

- Recessing buttons or levers below the surface of the control panel preventing engagement by casual or accidental contact.
- Bold and visible coding using colors, symbols, letters, or numbers reducing accidental engagements that result from mistakes in identification.
- Guards or covers being used to slow access to certain controls requiring more deliberation before acting. Guards or covers are especially effective if both hands are needed to access the control.
- Spacing controls far enough apart to prevent accidental engagement when using a neighboring control.
- Placing controls strategically to avoid accidental engagement during routine movements.
- Requiring sequential engagement of controls in a predetermined order.

Technological illiteracy

Technological illiteracy refers to a lack of knowledge or experience in broad or specific technology applications. This is a growing problem in societies and industries that are increasingly dependent on technology. When operations depend on technical knowledge, lack of training and experience can lead individual to behave in unsafe ways. One area of concern is cleaning personnel who are uneducated in the chemistry of cleaning agents and the reactions produced when using and mixing solvents. Additionally, in a work

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environment lack of knowledge about scientific principles such as force, energy, and movement can lead to actions that create unsafe conditions such as unbalanced loads, operating in unsafe locations, and overloaded structures or equipment. Research has shown that general and technological illiteracy often coexists, but are not dependent. Designers and engineers should create products and systems that maximize safety for those who are technologically illiterate.

Job stress

Job stress is an emotional and/or physical reaction caused by work-related factors. Stress causes tension and can contribute to illness. Job stress is most commonly found in faster-pasted, demanding work environments and contributes to work place safety. Analysis of workers compensation claims shows incidents of job stress have risen in recent years. Stress can produce many physical symptoms including rapid heartbeat, high blood pressure, sweating, headaches, and gastrointestinal problems. Ongoing job stress can cause serious health conditions. Job stress can be managed in a number of ways. Management should take steps to remove as many job stressors as possible and still maintain productivity as needed. Care should be taken not to unnecessarily increase work place stressors. Workers can be instructed in self-administered techniques such as deep breathing, meditation, and exercise. Sometimes job stress can be reduced by controlling other factors in an individual's life such as home, activity level, and family.

Warning techniques

Seven characteristics needed for effective communication of warnings include:

- Readability - is the intended audience's ability to receive the message being communicated; examples of techniques to improve readability include Braille, pictures, posting in multiple languages, and symbols
- Understandability – is the intended audience's ability to grasp the individual parts within the message being communicated
- Practicality – is the ability of the individual receiving a message to respond to a warning in suitable way

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- Comprehensibility – is the level to which an individual truly perceives the message being sent; simplicity, conciseness, and non-technical terms are vital
- Effectiveness – is the level to which a communication method or actual message has been tested for conveying a warning; no assumptions should be made about effectiveness without testing
- Behavior modification – refers to the ability of a communication method or actual message to produce the intended behavior from its audience
- Compatibility – refers to a communication method or message's agreement with the actual situation; a communication method or message must go with the warning being presented

Effective warning characteristics:

- Warnings should be placed in obvious, easy to see locations
- Warnings should be large enough to catch people's attention
- Warnings should utilize contrasting colors and unique designs that draw attention
- Materials used to design warnings should be long-lasting and hold up to environmental pressure
- Design and function of warnings should be dependable and always be at hand
- Warning devices must be addressed in training programs and frequently refreshed
- Attention catching elements such as brightness, color, and word choice that signal danger are important parts of warnings
- Warnings must be located in the optimal place and position for optimal visibility and audibility
- Unique and novel components of warnings such as animation improve audience attention
- Warnings should be categorized and designed according to intended function

Communication and safety outcomes

In order for workers to interact safely with the work environment, they must be aware of potential dangers. Communication is a key element of worker training. Communication

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incorporates a variety of workplace elements such as signage, direct management instructions, training programs, published procedures, warning devices, contingency plans, and checklists. Safe employee performance in routine operations and appropriate response to crisis or emergency situations is dependent on knowledge of safety procedures, potential dangers, and contingency responses. All of this can be communicated using the above mentioned techniques. Additionally, supervisors should provide feedback on performance to employees during training, normal operations, and crisis debriefing. Positive and negative reinforcement can also communicate to employees that actions are appropriate or inappropriate. This can include financial incentives, verbal comments, task assignment, awards, and employment sanctions.

Manufacturers seek to build products that achieve design goals and are free from defects. However, hazards can still exist if users are not made aware of proper storage, transportation, use, and intent. Under penalty of negligence and liability, manufacturers and suppliers have an obligation to insure that warnings meet the following guidelines:

- Warnings should be overtly obvious with almost certainty of being noticed due to easy visibility and stimulating nature.
- Categorization or purpose of the warning should be clear. Warnings can fall into the categories of reminders, explanations, or advisories.

In some scenarios visual warnings are not appropriate or sufficient. This requires the use of auditory warnings to work independently or draw attention to a secondary visual warning that is more informative about the situation. Auditory signals are often specifically constructed to particular emergencies and required responses and might include buzzers, sirens, bells, alarms, whistles, etc. Military Standard 1472 promotes the use of auditory warnings under the following conditions:

- Information is concise and simple demanding a quick response
- Auditory warnings should increase repetitiveness and overlapping under increasing critical nature
- Visual warnings are not useable

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- Individuals need to receive new data
- Habit and practice has conditioned individuals to auditory warnings
- Warnings should include verbal elements

Legal decisions have shown that a manufacturer, supplier, or even retailer's failure to advise users of dangers can be considered neglect or liability. Use of warnings can lessen the occurrences of accidents and mistakes by directing user attention to potential dangers. The American National Standard ANSI 2535.4-1991, "Product Safety Signs and Labels" has developed a standard approach to warnings considering level of seriousness. For maximum effectiveness a warning label should be easy to understand when read by most people. All warning labels should tell a user what actions should be taken or avoided in order to prevent injury, death, or damage. Additionally, warning labels should clearly state the possible effects of ignoring the warning.

Warning symbols are another method to indicate the presence of danger. Many such symbols have become standardized in their usage designated by government agencies and/or professional organizations. Some symbols that have gained national and international recognition are road signs and hazardous materials transportation indicators. Other resources include the FMC Corporation and Clark Equipment Company which have created a number of symbols.

The FMC Corporation publishes a manual that directs creation of warning labels and provides information about the related symbols for an extensive array of hazards. This resource includes color coding and information on multilingual warning systems. Another source of symbols and their uses is Drefuss' *Symbol Sourcebook*

Some warning symbols put forth by the Clark Equipment Company involve:

- A profile of a face sporting ear protection to show the need for this protective device
- A hand above a surface transmitting waves to show a hot surface

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- A profile of a face with objects moving toward eyes to show the need for eye protective devices
- A dropping arrow impacting a man's hat shows the danger of falling items
- A hand placed by an electrical cord putting out electricity to show the risk of shock
- Legs in the air above a wavy line to show a slippery surface
- Gears with a hand stuck between to show an area to keep hands away from

Symbols favored by the FMC Corporation involve:

- An individual located below a forklift to warn of the danger of that action
- An individual located on a forklift to warn of the danger of that action

Another type of warning devices is visual equipment that includes colored lights to classify dangers. Colored lights in warning devices are used as follows:

- Red indicates actual danger, emergency, breakdown, or stop
- Yellow indicates potential danger, less than optimal conditions, or need for caution
- Green indicates a situation that is routine, acceptable, or go
- White indicates that an operation or system can be accessed or is currently working

Machine-people interface

Machine-people interface refers to the way that individuals interact with machines. Machines display data for a user to receive. During reception, the user utilizes senses such as sight and sound to process the information with sight being the highest performing sense. This fact results in visual displays being the most common, with auditory controls coming in second. The user then analyzes and processes this information. By understanding the information received from a machine, the user is able to react using problem solving, decision making, memory, and judgment. If a user responds correctly to the information provided by the machine's controls, the machine should function as intended. Any interruption of the machine-people interface usually results in impaired performance. When the interruption is caused by the user, it is referred to as human error.

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Visual displays

Visual displays are the most common type since sight is the highest performing human sense. Visual displays commonly incorporate elements such as letters, numbers, and color coding. Additional elements that impact a user's ability to interpret information include specific color use, letter and number font, character size, and background pattern and color. Common types of visual displays include:

- Quantitative displays – show a specific value usually indicated with numbers; control indicators can include a fixed or moving scales or simple observation
- Qualitative displays – show the state or condition of a device or system; gives measurements that can not necessarily be assigned a specific value; often incorporates colors or words
- Representational displays – show conditions using symbols or other visuals such as animations, layouts, or maps

Procedures

Procedures are detailed process for completing tasks or objectives and are usually created to provide guidelines for implementing policy. Procedures offer itemized and precise steps for reacting to a variety of expected situations included possible crises and other events outside daily operations. Anytime policy, operations, or equipment is changed, new procedures must be designed and staff educated. Procedures should provide consistency and standardized behavior for different users and different applications. Some components of procedures include policy statements, directions for operations, possible exceptions to standardization, detailed instructions for complex scenarios, and required reporting and documentation.

In order to create appropriate procedures, careful attention is given to all aspects of an operation by conducting a complete evaluation of all components. During this evaluation consideration is given to equipment, types of tasks, production design, human nature, and the calculation of all related costs. Additionally, a lot of focus is directed to determining all potential hazards and risks and identifying related safety devices, programs, and controls.

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Analysis should consider all possible safety scenarios and the development of appropriate responses, even if probability is very low. As each aspect of normal operations and possible non-routine occurrences is explored, specific step-by-step information should be developed that reduces the possibility of human error and the resulting injuries and property damage

Special safety procedures are designed to address non-routine scenarios such as unexpected emergencies or the development of unusually hazardous conditions. This type of procedure begins with a description of authority and chain of command which might vary from routine situations. These procedures should be designed to accommodate human behavior during crises which can lead to poor judgment and mistakes by providing extensive step-by-step detail for action. Procedures should explain the consequences of not following the stated guidelines. An example of special safety procedures is a permit system which analyzes conditions related to a particular operation each time it is scheduled to occur. Operations are restricted until conditions are verified to be safe.

Procedures can be divided into several levels. Levels are determined by the nature of the task to be performed. Levels can be created based on task difficulty, duration or recurrence, and specialization or responsibility. Creating levels of procedures helps employees manage routine decisions as well as establishing a plan of response to non-routine occurrences. An example of procedural levels might be responses to an equipment malfunction. A first level response might include the worker making routine checks for common problems that could cause the malfunction. A second level procedure would be to inform a supervisor who might investigate himself or contact an equipment specialist. A third level procedure requiring management approval would be to run diagnostic tests and possible order outside repairs or equipment replacement.

Rescue procedures

Emergency or crisis scenarios mean the chance that individuals may become trapped and unable to exit a facility. Prior to this situation occurring, provisions should be made for

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rescuing any trapped individuals. Rescue might have to be conducted by people familiar with the products and procedures of the facility, those knowledgeable about the dangers present in the facility, or those lacking knowledge but willing to help. Prior to the arrival of highly trained rescue personnel, less qualified individuals might be able to help. To facilitate this, facilities should install and clearly mark rescue and emergency equipment. These devices can serve specific purposes such as an airplane canopy release or be more general in nature such as an ax, a motorized vehicle, or oxygen tanks.

Monitoring devices

Monitoring devices or systems are used proactively in order to ensure that conditions within a system or facility do not become hazardous. Examples include pressure or temperature gauges, scheduled visual inspections, and air quality devices. Some conditions that can be determined by monitoring systems include:

- The existence of particular conditions
- The readiness of a part or system to engage
- If a system is operating as intended
- If an unacceptable situation is occurring
- If identified limits are being exceeded
- If calculated indicators are not routine

A monitoring device or system must coexist with some type of warning system to indicated hazardous conditions and initiated steps to remedy the identified situation. Monitoring devices can also include automated shut off switches and fire protection devices.

The monitoring process includes four key components: detection, measurement, interpretation, and response.

- Detection is the step of identifying levels and operating conditions for the system. A monitoring device must determine dangerous or abnormal conditions early enough or at a low enough level for response to be effective in an emergency. This means sensors and indicators must be optimally located for fast response.

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- Measurement examines the ideal levels and conditions and compares this to the current situation to check for problems.
- Interpretation is the process of examining measurements to determine if warnings or corrective actions are needed. This means that the device and/or operator must understand the meaning of irregularities.
- Response includes action taken based on detection, measurement, and interpretation. Monitoring systems and devices should include elements that indicate required responses.

Project cost

A CSP might determine that a four inch water main needs to be extended to properly irrigate an additional area. This particular area measures about 200,000 square feet. Each sprinkler head covers about 125 square feet. The water main will have to be extended by 400 feet in order to reach the area. The estimates indicated that the additional water pipe will cost $1200 per foot to install. Also, each sprinkler head will incur a $350 expense and the entire project will involve about $150,000 in non-categorized plumbing costs. The control device for the new system will be $150,000. The CSP can calculate an estimate of the total cost of the project for the feasibility study as follows:

Cost of water main = 400 feet of pipe X $1200/ft = $480,000

Cost of sprinkler = 200,000 total square feet/125 square feet per head X $350 = $560,000

Total Cost = $480,000 + $560,000 + $150,000 + $150,000 = $940,000

Threshold limit value

Consider the following data:

- A solvent mixture includes 50% solvent X, 25% solvent Y, and 25% solvent Z
- A test of the air indicates that solvent Z is present in a concentration of 20 ppm
- The eight hour threshold limit values (TLV) for solvent X = 100 ppm, solvent Y = 50 ppm, and solvent Z = 50 ppm

TLV for each of the elements in the mixture can no go beyond a combination of 1.0 as shown in the following formula:

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$C1/T1 + C2/T2 + \ldots + C_n/T_n$ is less than or equal to 1

If evaporation is proportional for the entire mixture the following formula could be used:

X= [(0.50/0.25) (20ppm)] then X = 40ppm
Y = [(0.25/0.25) (20ppm)] then Y = 20ppm
40ppm/100ppn =20ppm/50ppm + 20ppm/50ppm = 1.2
This means that the TLV has been surpassed.

Hazard analysis reports

Hazard analysis reports can be a productive element of a safety program. The following are some of their benefits:

- Identifying potential hazards in order to implement controls or design changes to avoid unintended effects
- Confirmation of optimal design including appropriate safety elements
- Confirmation that specific hazards are controlled or eliminated
- Determination of compliance with design standards and regulatory guidelines
- Identifying specific product hazards or design problems prior to production
- Verification of reports or analysis from other sources
- Elimination of the need for additional testing of product safety

Company records

In manufacturing, companies and organizations are accountable for the products they produce and pass along to consumers. Keeping careful records of all aspects of production, testing, and quality control provides several safeguards for manufacturers and ultimately, consumers. These records allow organizations and companies to track and control changes in processes, document required tests and inspections, and show corrective actions taken. Individual batches or shipments can also be tracked if questions of quality or defects arise. Consumer claims of neglect or defective products can be better addressed with records of successful inspections or testing. All personnel responsible for product specifications and

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limits must be well-trained in recognizing areas of deficiency and keeping good records to document product compliance. Suppliers and vendors who sell to manufacturers are also responsible for all these actions for the components and raw materials they provide.

Discrete and continuous controls

Continuous controls are based on the relationship between control movement and display results. This is known as the C/D ratio and is calculated based on the amount of movement on a display that is produced by a certain movement of the control. Examples of this type of control include joysticks, steering wheels, and a computer mouse. The main feature of continuous controls is the ability to highly regulate results using either fast, slewing motions or small movements for smaller adjustments. Discrete controls feature fixed positions and send very specific data. This type of control allows less user power to regulate actions. Discrete controls include keyboards, basic switches, buttons, and keys.

Block and tackle

A block and tackle make up equipment designed to lift materials. Certain weight limits are prescribed for safety when using this device so that falling materials or unstable loads can be avoided. When hoisting materials using a block and tackle, the equipment must be placed on a level surface for stability. All chains and ropes to be used must be checked for tangles. Force is distributed when using a block and tackle based on the free ropes or chains that attach to the pulley. Different sizes of equipment and different design components dictate weight limits. The following formula shows how vertical force is calculated when using this device: $F = W/3$ where F=force, W=weight and 3=number of ropes or chains connected to pulley.

Electrical grounding

Grounding is the effect of control the exchange of electricity between two or more objects. Grounding establishes a boundary that impedes the flow of an electrical charge or current from one object to another. This involves establishing conductors between objects that are both charged and eliminated the charge. This stops the flow of electrical current that can

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present the risk of shock. One approach to grounding places a copper rod in the ground with connectors. Local, state, and professional codes indicate grounding requirements including the size of connectors and materials to be used. Metal in buildings or other structures can be grounded if minimal resistance to the surface is present. Grounding can also keep individuals from being electrocuted.

Density can be scientifically calculated by the following formula: d=m/v where d=density, m=mass and v=volume. Density is a determination of how compact an object or substance is. Substances or objects of the same dimensions can have significantly varying densities. For example, lead is high density while Styrofoam is much lower. Density is influence by the nature or characteristics of a material, not by its size or dimensions. For example, a bar of silver and a silver coin share the same density, even though their size and mass are quite different. Density of matter in different forms is noted differently. Solids and liquids are shown as g/cm^3 where g=gram and cm^3 =cubic centimeters. Alternately, gases are shown as g/dm^3 where dm^3 =cubic decimeters.

Current density refers to the quantity of electrical current that is moving through a conductor into a specified area. Units of measurement are determined by the unit of measurement defining the area to be considered. The larger the area, the lower the current density will be. Resistivity is an element of electrical movement. Electricity moves differently through different materials. When electricity moves, it often follows a path that involves more than one substance or material. Resistivity is also measured based on a specified area into which an electrical current passes. The following formula is used to calculate resistivity for a specific area (R): R = pl = 1/o~ where p=resistivity measured in ohms and o~=conductivity. Data gathered from resistance tables provides information on different materials.

Conflict resolution

Conflict resolution, also known as Alternative Dispute Resolution (ADR) developed from the idea that better options existed to resolve conflict than the common human reaction of

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violence or lawsuits. Conflict resolution has become a popular option for working out problems between individuals or groups. Several different methods are used including the following:

- Arbitration is a technique involving an impartial third party who considers the evidence in the situation as well as the positions and arguments posed by each side. The third party, known as an arbitrator, makes a decision to resolve the situation. This approach is commonly used in labor disagreements and negotiations with management.
- Mediation also involves an impartial third party. Both sides in a disagreement agree to use the mediator's services. The mediator acts as a facilitator opening lines of communication, prompting discussion, guiding each party to understand the issues clearly, helping to create a plan for resolution, and working with both parties to formalize an agreement. The mediator does not have authority to force either party to participate or agree to certain conditions.

Conflict resolution is a common approach to resolving differences in an attempt to avoid costly litigation or lengthy periods of required attention. Conflict resolution has become very popular as a tool to work through disagreements between labor and management in businesses. This approach is strongly encouraged by the U.S. Department of Justice through its national mediation program used to resolve complaints made under the Americans with Disabilities Act. The U.S. Supreme Court has also sided in favor of using arbitration instead of the courts in *Circuit City Stores v. Adams*, upholding the practice in employment disputes if employees had agreed to arbitration if needed as a condition of employment. About 8% of employees are currently required to agree to such contracts. Conflict resolution can promote individual control of situations, improved cooperation, privacy, and prompt attention to problems.

More companies are turning to conflict resolution methods to resolve problems in the work environment or employer/employee relationship. Many corporate entities have embraced this idea in company policies and practices such as workplace mediation, peer review, and

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employee hot lines. Ombudsman is Swedish term that refers to a "representative". Large companies or entities often employ one or more ombudsmen who bear the responsibility or investigating complaints or concerns, maintaining impartiality, and suggesting action or change to management or a board of directors. For this position to work successfully, it must be protected from fear of retaliation, termination, or demotion. This is often accomplished by having the ombudsman's office answer directly to the company's board of directors with no accountability to management.

Conflicts are addressed and disagreements settled in a number of different ways including the following:

- Consensual dispute resolution involves the disagreeing parties in determining what process will be followed to solve the dispute and what outcome is acceptable to each. This process is facilitated by a conciliator who works individually with both parties through face-to-face meetings, negotiations, and mediation.
- Adjudicative resolution involves an impartial third party who determines a final resolution that is binding to all parties. The adjudicator makes the decision after examining related evidence and testimony. This process is often court-ordered.
- Legislative resolution can be applied to broad or commonly occurring disputes. This involves the legislative leadership of a government entity or a private organization creating governing mandates that clarify particular situations. Disagreements involving the application of these mandates involve consensual or adjudicative approaches.

Computer tools

Specific computer systems such as CAD or computer aided design can improve safety by determining risks or hazards present in the workplace. This type of system can evaluate the many different layers within an environment such as physical features like flooring, electronics such as alarms and warning devices, individual components such as equipment, floor plan details, and various operations that take place. CAD utilizes drawing, colors, and patterns to indicate specifics and call attention to certain areas. CAD and database

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management systems (DBMS) can work together, integrating information for better analysis. Information can be gathered and distributed by different criteria such as department, risk level, or type of operation.

Document management is a process that is usually completed with specific technological applications. Its purpose is to gather, store, and produce the variety of documents that are generated as part of an operation. This can involve paper and electronic forms, image capture, and correlation of information. This can include any number of document types. In safety programs, these documents could include equipment purchase and maintenance records, employee training, inspection reports, legal compliance documentation, and materials tracking. Data banks are created from documents and other sources of information to provide people with needed extensive safety related data such as legal requirements and compliance, regulatory guidelines, accident statistics, material specifications, and much more. Data banks can be maintained privately by an industry or company. Often, they are maintained by companies that charge others a usage or subscription fee for access.

Database management systems

Computer systems such as data base management (DBMS) allow safety professionals to analyze and disseminate information related to safety. DBMS systems are more efficient by reducing the number of programming functions that must be performed. Computer based training (CBT) is a system for training employees that also monitors training completion, refresher, compliance, and performance. It allows employers to efficiently train workers on an ongoing basis while producing detailed records of the training and its results. CBT has the advantages of removing the stress of performing in front of co-workers and providing prompt feedback to trainees. Many CBT programs are technologically advanced and offer a great medium for presentation of information, testing, and organization of entire programs.

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Hardware and software problems

Computer generated hazards are often difficult to identify and can increase in destructiveness quickly. Computer software and hardware should be tested thoroughly for problems to prevent damage or loss. If complete testing has been accomplished, planning should take place to address potential problems that could occur down the road. Computer malfunctions can be caused by numerous factors such as electromechanical breakdown in the CPU, software programming errors, operator error, connection problems, or faulty hardware. Computers themselves cannot make errors so problems must be generated by software, hardware, or user action. Software malfunctions have a tendency for repetitive incidents of the same problem. Computer problems are categorized as zero, erratic, non-programmed products, unintended results, or degraded.

Compatibility

Compatibility describes how different elements in an environment work together. A compatibility relationship can describe the responses that people exhibit when exposed to certain prompts and the outcomes they expect. This type of compatibility can be specific to cultural exposure and condition. One example is the compatibility relationship between the red, yellow, and green lights on a traffic control device and the resulting human reaction of stopping the vehicle, slowing the vehicle or proceeding carefully, and continuing to move forward. Another example would be the reaction of turning a steering wheel to the left in response to a need to turn left and the expectation that turning the wheel will cause the wheels to follow. A third example might be reaction of exiting a building upon hearing an alarm sound continuously. Compatibility relationships are an element of the design process that must be carefully considered since people frequently observe these relationships almost subconsciously.

Controlling resistance

Four methods commonly used to create resistance in a device are friction, springs, viscous damping, and inertia. A number of factors must be considered when designing resistance since the nature of control resistance can impact reaction time, user health, level of control,

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and accident occurrences. If resistance is not high enough, users do not perceive it easily and make more mistakes. Overly strong resistance leads to user fatigue and slower reaction times. Design using elastic resistance should factor for increased force at greater distances and the need for a user to add neutral positioning to the elastic force for maximum control.

Fuel and energy

The body uses two different methods to convert carbohydrates, lipids, and fats into usable energy for the body. The first method is aerobic or using oxygen to break down fuel and produce energy. This type of action occurs when people engage in activities such as running, swimming, cycling or similar exercise options that increase the body's use of oxygen. This is the primary method used to create energy. The other method is anaerobic which breaks down carbohydrates without the use of oxygen and ultimately produces smaller amounts of energy than aerobic. This is accomplished by dividing glucose molecules into smaller pieces. An example of anaerobic activities is a short duration of heavy weight lifting.

Heat exchange

Body temperature refers to the specific amount of heat that a person generates. Heat can be exchanged between a person and his environment through convection, radiation, and evaporation. Convection is the process of moving heat through shifts in the air. The amount and speed of heat exchange is influenced by the environment's air speed. Body temperature can be increased or decreased in this exchange depending on environment temperature. Radiation can also increase or decrease heat. This type of transfer occurs simply from differences in temperature in a human body and its surrounding environment. A warmer environmental temperature will increase body temperature. Evaporation is the third type of exchange and one that reduces body temperature through the dissipation of sweat. The rate and speed of exchange is also influenced by the temperature of the environment.

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Anthropometry

Anthropometry is the science of how various measurements of the human body and other physical traits relate to people's lives. Scientists in this field gather two types of data. The first are static measurements which encompass the height, length, and width of various parts of the body in a variety of positions. The other type of data is functional data which includes aspects such as strength, range of motion, and movement. Scientists analyze the data that they gather by recording it according to gender and percentile ranking based on total population numbers. Some of the tools used by scientists to record data include calipers, anthropometers, and goniometers for joint angles. This data can be used by engineers and designers to develop equipment, operations, and systems that address the safety concerns presented by a diverse work population

Ergonomics

Ergonomics is a growing scientific field that focuses on maximizing productivity, efficiency, and worker safety and comfort through workspace design. Ergonomics is sometimes referred to as human engineering or human factors engineering. The goal of ergonomics is to choose environmental elements that make employees safe and comfortable which in turn improves their productivity. This means that a workspace should be made to fit the worker, not the other way around. Elements that are considered by this field of study and design are extensive and can include desk height and placement, chairs, flooring materials, lighting type and placement, vehicle design, font size and type in printed materials, temperature control devices, equipment components, ventilation, door handles, and architectural design. Ergonomics are not limited to any one industry or field, but instead are applicable to every occupation. The benefits of sound ergonomic design include reducing injuries and illnesses, employee satisfaction, increased production, fewer insurance claims, compliance with government mandates, and more efficient use of manpower and materials.

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Some general principles used in ergonomics include:

People v. machine

Humans and machines have varying capabilities and strengths that should be utilized in design decisions. For example humans can better distinguish different audio signals in a noisy environment. However, machines are more adept at completing repetitive functions with exactness.

Designing jobs to fit people

Jobs should be designed with a specific individual in mind. Careful attention should be given to a person's qualifications. If a person is expected to adjust to a job or task for which they do not have the required skills, the likelihood of mistakes and accidents increases. Job expectations should be adjusted to fit the individual.

Work smart, not hard

Increasing productivity and efficiency should not be accomplished by asking workers to do more, but rather by determining a better way to accomplish the goal.

People are not alike

During the design process for equipment, operations, buildings, or entire systems, designers and engineers do not know the individual characteristics of workers who will ultimately use these resources. Designers should consider the unknown of elements such as skill level, physical size, and attitudes.

Data gathered by scientists is used to created work environments that are safe by considering human elements such as reach, fit, and accessibility. This type of design incorporates several key ideas including the following:

- Designs should accommodate a variety of users by allowing for adjustments. Examples include monitors with adjustable heights, chairs with adjustable seat height, and automobile seats that allow different drivers to adjust proximity to the pedals and steering wheel.
- Although not every element of a work environment can be adjusted to meet the differences people present, a common standard to apply when possible is a design

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that allows a male in the 95% percentile to fit and a female in the 5th percentile to reach.

- A designer should be cognizant of the intended user. If specific data is available, that should be a key element of design considerations. If no specific information about users can be obtained, general data gathered by anthropometric scientists can be used and design conducted to serve as large a population as possible.

Work force and population demographics have seen significant shifts in recent years. Individuals are living longer, increasing the average age. More disabled individuals are seeking employment and the percentage of women employees is also increasing, especially in traditionally male jobs. Age and disability factors are increasing the use of work station and equipment design to accommodate limited range of motion. Many employers are making required accommodations for disabled workers under federal law and larger employers cannot refuse jobs to qualified disabled individuals because of the disability if reasonable accommodations would allow them to perform the job. These accommodations often involve work space, equipment, and building use. The typically smaller size of women has generated a greater need for work station design, equipment, and protective devices that are easily adapted to smaller individuals.

The following principles should be considered when designing a workstation:

- Importance – elements of the workstation that are the most critical to the work performed should be placed in the immediate proximity of the user's vision and access
- Frequency of use – elements of the workstation that are used most often should be given priority in location most convenient to the user
- Functionality – related elements of the workstation or those which are dependent upon one another should be strategically placed to maximize the efficiency of that relationship

Sequence of use – elements of the workstation should be organized in a design that facilitates logical movement from one task to another with maximum efficiency, avoiding unnecessarily repetitive movements

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Cash flow

The analysis of money going in and out of an entity is cash flow. If the rent is due on Thursday and you are paid on Friday, you have a cash flow problem. All cash flow analysis is dependent upon the business entity of interest. A cash flow out from one business entity is a cash flow in for another entity. Paying the rent is a cash flow out for the renter but is a inflow of cash for the landlord. A cash flow diagram is a chart with the horizontal axis of time with money coming in as an up arrow and money going out as a down arrow. At any point in time, the sum of cash in and out can be represented by individual arrows or a single arrow with the sum. Money cash flow can be a single payment, a uniform series of equal values of money at regular time intervals, or gradient series of increasing or decreasing values of money at regular time intervals.

Time value of money

When money is invested in a safe banking type institution, it can accumulate or accrue interest. The amount of interest earned is called the accrued amount. The interest amount is based on the amount of the investment, the length of time it is invested, and the interest percentage rate. If the money is invested over several time cycles then the interest is calculated differently. At the end of each time cycle the interest is calculated on the increased investment amount which is known as compounded interest. The effective interest rate is the interest rate between compounding cycles. If the effective interest rate is calculated over a year it is known as the effective annual interest rate.

Discount factors

A technique for comparing various cash flows is the use of discount factors. The comparison of cash flows can be done at the current time called the present worth or it can be done at some time later known as the future worth. Cash flows are also be compared on an annual amount basis. There are tables of discount factors for one time cash flows in or out known as single payment compound amount factor. There are also discount factor tables for cash flows that repeat and are known either known as uniform series if the amount is unchanging or gradient series if the amounts increase or decrease over time.

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When you calculate present or future worth of two or more cash flows and they are the same value then the cash flows are equivalent. Typically equivalence is not the goal of cash flow calculations; normally you are trying to minimize negative cash flows or maximizing positive cash flows.

Functional Notation

There are many discount tables that convert cash flows from one type to another equivalent type. The names for these tables are not standardized and take many characters to identify so a short hand version has been devised known as functional notation. Function notation uses a three terms separated by commas between parentheses. The first term indicates the first letter of the type of cash flow you are starting with and the type of cash flow you wish to calculate separated by a vertical line. The four cash flows are identified by Present (P), Future (F), Annual (A), or Gradient (G). The second term of the functional notation is the interest rate and the third term is the number of cycles. If you want the discount factor for present value given a future value at five percent annual interest rate for four years, you would look for the (P|F,5%,4) discount factor.

Discontinuous and random compounding

Normally interest on an investment or a loan is compounded on some recurring basis thus it is called compound interest. This recurring basis may or may not be an annual time period. If it is not annual then it is simply known as the nominal interest rate or for money invested in banks it is sometimes referred to as the yield, identified by r. Between the periods of compounding, interest may be calculated on the investment or loan amount. The effective interest rate, identified as i, is the nominal interest rate divided by the number of time periods between the compound time periods.

Continuous Compounding

For almost all normal investment or loan situations, interest is calculated on a discrete time basis such as monthly, quarterly, or yearly. The discrete compound interest discount factors can be found in tables. There are some situations that the interest is compounded

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every day, such as credit cards where purchases are made while there is an outstanding balance. Compounding interest everyday or more often is known as continuous compound interest. The continuous interest discount factors are not normally listed in tables and can be calculated using exponential equations using the nominal interest rate, r, and the time period in years, n.

Straight line and accelerated depreciation

For most people, depreciation is the decrease in value in a piece of equipment due to use or misuse over time. For the Internal Revenue Service, depreciation is the calculated annual expense that takes a single large purchase and distributes it over several years. The current tax laws, type of purchase and amount determines how large a purchase has to be to be depreciated and how it should be calculated. First the depreciation basis must be calculated which is the purchase price minus the salvage value. The simplest depreciation calculation is called the straight-line depreciation method which uses the depreciation basis divided by the number of years between the purchase and the salvage time. The Accelerated Cost Recovery System (ACRS) or the Modified Accelerated Cost Recovery System (MACRS) uses a series of factors to determine the amount of depreciation each year. Depreciation is in engineering economics because comparing similar purchases may have different depreciation basis or depreciation schedules.

Calculation of book value

The book value, BV, is a calculated amount that starts with the purchase price and subtracts the accumulated depreciation or the sum of all the depreciations, regardless of how the depreciation is calculated. The book value is normally calculated at the end of each year although some companies apply depreciation on a monthly basis. The original book value is the same as the purchase price until depreciation is applied whether that is a month or at the end of the end whichever is used by the company. The book value or the ratio of the book value to the initial purchase price is used by many depreciation schemes.

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Equivalent uniform annual cost

Besides comparing the value or cost of various cash flows at present or future worth, there is another common technique known as the Equivalent Uniform Annual Cost or EUAC. Where present or future worth provide positive values for incoming monies and negative values for outgoing monies, the EUAC is a cost so positive values are for outgoing monies and negative values for incoming monies. The EUAC is useful for comparing large infrastructure projects that may have very different lifetimes. The Equivalent Uniform Annual Cost, as it sounds, is the sum of all the negative cash flows minus the sum of all the positive cash flows divided by the number of years the cash flows occur.

Capitalized cost

Capitalized cost is the present worth of an infinitely long cash flow scenario that requires no other expenses to continue the scenario by way of compound interest. The idea is if you had the entire capitalized cost sitting in the bank earning interest, the project would never run out of money. The discount factors for infinite time periods are not listed but the present value of an infinite series is the equivalent uniform annual cost (EUAC) divided by the interest rate. Since capitalized cost is expenses, a negative number means that incoming future money exceeds the cost of the cash flow scenario which is typical in commercial ventures but rarely occurs with large infrastructure projects.

Alternative economic comparisons

Rarely engineering projects have no design tradeoffs. When the outcomes of these design tradeoffs produce similar results then the preferred approach must be selected using some form of economic analysis. There are five normal economic comparison tools commonly used with pros and cons for each tool. The comparisons are Present Worth Analysis which simply looks for the maximum present worth of competing scenarios, Annual Cost Analysis which simply looks for the minimum EUAC, Rate of Return Analysis which looks for the highest interest rate, Benefit-Cost Analysis which looks at where benefits for different users and cost to all, and Break Even Analysis which looks at the shortest time until the project pays for itself.

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Break even analysis

One of the five common economic comparisons is break even analysis. In the simplest terms, break even analysis looks at the shortest time or minimum number of units until the project pays for itself. This analysis is sometimes known as determining the payback period. To use break even analysis, the projects must have costs and generate revenue so this is usually limited to commercial ventures and not government infrastructure projects. If a project ends before the break even or pay back occurs then the project will be a net loss for the company. At any time after the break even occurs, the company will expect a new profit.

Benefit cost analysis

One of the five common economic comparisons is the benefit cost analysis. Of the five economic comparison techniques, the benefit cost analysis is easily the most complicated to perform and is also most subjective in nature. In simple terms, the benefit cost analysis looks at where benefits will occur for different users and total cost to everyone. Benefit cost analysis is not normally applied to commercial projects unless they are extremely large and is normally applied to government projects. The sum of the benefits divided by the sum of the costs should be greater than one for an acceptable project. When comparing multiple projects, the highest ratio will determine the best project. The exact sum of benefits and costs are sometimes difficult to accurately determine – a benefit to one group may be a cost to another group.

Worth and cost analysis

Two of the five common economic comparisons are present worth and annual cost analysis. These two comparisons are very similar despite one being opposite signs or values. In simple terms, present worth analysis looks for the maximum present worth of competing scenarios. Annual cost analysis simply looks for the minimum Equivalent Uniform Analysis Cost (EUAC) and is sometimes referred to as annual return method or the capital recovery method. Both these comparisons use standard discount factors to calculate the present worth or the annual cost of the respective scenarios. Both of these

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analysis require the projects of interest to be mutually exclusive. Both of these types of analysis are simple to apply to commercial or government projects, although present worth is rarely used for government analysis.

ROR

One of the five common economic comparisons is the rate of return cost analysis or simply known as ROR. The Rate of Return Analysis looks for the highest interest rate of competing cash flow projection scenarios. A simpler definition is how much interest would I earn if I put that amount of money in a bank and coincidentally that is also a measure of whether you should do a project is would the money have been better off sitting in a bank instead of risked on this venture. This minimum acceptable interest rate is known as the minimum acceptable rate of return or MARR and is established by the company. Some companies use different MARR values for different projects or project lengths.

Probability

Probability is a branch of statistics that deals with the likelihood of something taking place. One classic example is a coin toss. There are only two possible results: heads or tails. The likelihood, or probability, that the coin will land as heads is 1 out of 2 (1/2, 0.5, 50%). Tails has the same probability. Another common example is a 6-sided die roll. There are six possible results from rolling a single die, each with an equal chance of happening, so the probability of any given number coming up is 1 out of 6.

Terms frequently used in probability:
Event – a situation that produces results of some sort (a coin toss)
Compound event – event that involves two or more independent events (rolling a pair of dice; taking the sum)
Outcome – a possible result in an experiment or event (heads, tails)
Desired outcome (or success) – an outcome that meets a particular set of criteria (a roll of 1 or 2 if we are looking for numbers less than 3)

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Independent events – two or more events whose outcomes do not affect one another (two coins tossed at the same time)
Dependent events – two or more events whose outcomes affect one another (two cards drawn consecutively from the same deck)
Certain outcome – probability of outcome is 100% or 1
Impossible outcome – probability of outcome is 0% or 0
Mutually exclusive outcomes – two or more outcomes whose criteria cannot all be satisfied in a single event (a coin coming up heads and tails on the same toss)

Probability is the likelihood of a certain outcome occurring for a given event. The **theoretical probability** can usually be determined without actually performing the event. The likelihood of a outcome occurring, or the probability of an outcome occurring, is given by the formula

$$P(A) = \frac{\text{Number of acceptable outcomes}}{\text{Number of possible outcomes}}$$

where $P(A)$ is the probability of an outcome A occurring, and each outcome is just as likely to occur as any other outcome. If each outcome has the same probability of occurring as every other possible outcome, the outcomes are said to be equally likely to occur. The total number of acceptable outcomes must be less than or equal to the total number of possible outcomes. If the two are equal, then the outcome is certain to occur and the probability is 1. If the number of acceptable outcomes is zero, then the outcome is impossible and the probability is 0.
Example:
There are 20 marbles in a bag and 5 are red. The theoretical probability of randomly selecting a red marble is 5 out of 20, (5/20 = 1/4, 0.25, or 25%).

When trying to calculate the probability of an event using the $\frac{desired\ outcomes}{total\ outcomes}$ formula, you may frequently find that there are too many outcomes to individually count them. Permutation and combination formulas offer a shortcut to counting outcomes. A permutation is an arrangement of a specific number of a set of objects in a specific order.

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The number of **permutations** of *r* items given a set of *n* items can be calculated as ${}_nP_r = \frac{n!}{(n-r)!}$. Combinations are similar to permutations, except there are no restrictions regarding the order of the elements. While ABC is considered a different permutation than BCA, ABC and BCA are considered the same combination. The number of **combinations** of *r* items given a set of *n* items can be calculated as ${}_nC_r = \frac{n!}{r!(n-r)!}$ or ${}_nC_r = \frac{{}_nP_r}{r!}$.

Example: Suppose you want to calculate how many different 5-card hands can be drawn from a deck of 52 cards. This is a combination since the order of the cards in a hand does not matter. There are 52 cards available, and 5 to be selected. Thus, the number of different hands is ${}_{52}C_5 = \frac{52!}{5!\times 47!} = 2{,}598{,}960$.

Sometimes it may be easier to calculate the possibility of something not happening, or the **complement of an event**. Represented by the symbol $\bar{A}$, the complement of A is the probability that event A does not happen. When you know the probability of event A occurring, you can use the formula $P(\bar{A}) = 1 - P(A)$, where $P(\bar{A})$ is the probability of event A not occurring, and $P(A)$ is the probability of event A occurring.

The **addition rule** for probability is used for finding the probability of a compound event. Use the formula $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$, where $P(A \text{ and } B)$ is the probability of both events occurring to find the probability of a compound event. The probability of both events occurring at the same time must be subtracted to eliminate any overlap in the first two probabilities.

Conditional probability is the probability of an event occurring once another event has already occurred. Given event A and dependent event B, the probability of event B occurring when event A has already occurred is represented by the notation $P(A|B)$. To find the probability of event B occurring, take into account the fact that event A has already occurred and adjust the total number of possible outcomes. For example, suppose you have ten balls numbered 1–10 and you want ball number 7 to be pulled in two pulls. On the first pull, the probability of getting the 7 is $\frac{1}{10}$ because there is one ball with a 7 on it and

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10 balls to choose from. Assuming the first pull did not yield a 7, the probability of pulling a 7 on the second pull is now $\frac{1}{9}$ because there are only 9 balls remaining for the second pull.

The **multiplication rule** can be used to find the probability of two independent events occurring using the formula $P(A \text{ and } B) = P(A) \times P(B)$, where $P(A \text{ and } B)$ is the probability of two independent events occurring, $P(A)$ is the probability of the first event occurring, and $P(B)$ is the probability of the second event occurring.

The multiplication rule can also be used to find the probability of two dependent events occurring using the formula $P(A \text{ and } B) = P(A) \times P(B|A)$, where $P(A \text{ and } B)$ is the probability of two dependent events occurring and $P(B|A)$ is the probability of the second event occurring after the first event has already occurred.

Before using the multiplication rule, you MUST first determine whether the two events are dependent or independent.

Use a combination of the multiplication rule and the rule of complements to find the probability that at least one outcome of the element will occur. This given by the general formula $P(\text{at least one event occurring}) = 1 - P(\text{no outcomes occurring})$. For example, to find the probability that at least one even number will show when a pair of dice is rolled, find the probability that two odd numbers will be rolled (no even numbers) and subtract from one. You can always use a tree diagram or make a chart to list the possible outcomes when the sample space is small, such as in the dice-rolling example, but in most cases it will be much faster to use the multiplication and complement formulas.

Expected value is a method of determining expected outcome in a random situation. It is really a sum of the weighted probabilities of the possible outcomes. Multiply the probability of an event occurring by the weight assigned to that probability (such as the amount of money won or lost). A practical application of the expected value is to determine whether a game of chance is really fair. If the sum of the weighted probabilities

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is equal to zero, the game is generally considered fair because the player has a fair chance to at least to break even. If the expected value is less than zero, then players lose more than they win. For example, a lottery drawing might allow the player to choose any three-digit number, 000–999. The probability of choosing the winning number is 1:1000. If it costs $1 to play, and a winning number receives $500, the expected value is $\left(-\$1 \cdot \frac{999}{1{,}000}\right) + \left(\$500 \cdot \frac{1}{1{,}000}\right) = -0.499$ or $-\$0.50$. You can expect to lose on average 50 cents for every dollar you spend.

Most of the time, when we talk about probability, we mean theoretical probability. **Empirical probability**, or experimental probability or relative frequency, is the number of times an outcome occurs in a particular experiment or a certain number of observed events. While theoretical probability is based on what *should* happen, experimental probability is based on what *has* happened. Experimental probability is calculated in the same way as theoretical, except that actual outcomes are used instead of possible outcomes.

Theoretical and experimental probability do not always line up with one another. Theoretical probability says that out of 20 coin tosses, 10 should be heads. However, if we were actually to toss 20 coins, we might record just 5 heads. This doesn't mean that our theoretical probability is incorrect; it just means that this particular experiment had results that were different from what was predicted. A practical application of empirical probability is the insurance industry. There are no set functions that define life span, health, or safety. Insurance companies look at factors from hundreds of thousands of individuals to find patterns that they then use to set the formulas for insurance premiums.

Objective probability is based on mathematical formulas and documented evidence. Examples of objective probability include raffles or lottery drawings where there is a pre-determined number of possible outcomes and a predetermined number of outcomes that correspond to an event. Other cases of objective probability include probabilities of rolling

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dice, flipping coins, or drawing cards. Most gambling games are based on objective probability.

Subjective probability is based on personal or professional feelings and judgments. Often, there is a lot of guesswork following extensive research. Areas where subjective probability is applicable include sales trends and business expenses. Attractions set admission prices based on subjective probabilities of attendance based on varying admission rates in an effort to maximize their profit.

The total set of all possible results of a test or experiment is called a **sample space**, or sometimes a universal sample space. The sample space, represented by one of the variables S, Ω, or U (for universal sample space) has individual elements called outcomes. Other terms for outcome that may be used interchangeably include elementary outcome, simple event, or sample point. The number of outcomes in a given sample space could be infinite or finite, and some tests may yield multiple unique sample sets. For example, tests conducted by drawing playing cards from a standard deck would have one sample space of the card values, another sample space of the card suits, and a third sample space of suit-denomination combinations. For most tests, the sample spaces considered will be finite.

An event, represented by the variable E, is a portion of a sample space. It may be one outcome or a group of outcomes from the same sample space. If an event occurs, then the test or experiment will generate an outcome that satisfies the requirement of that event. For example, given a standard deck of 52 playing cards as the sample space, and defining the event as the collection of face cards, then the event will occur if the card drawn is a J, Q, or K. If any other card is drawn, the event is said to have not occurred.

For every sample space, each possible outcome has a specific likelihood, or probability, that it will occur. The probability measure, also called the distribution, is a function that assigns a real number probability, from zero to one, to each outcome. For a probability measure to be accurate, every outcome must have a real number probability measure that is greater

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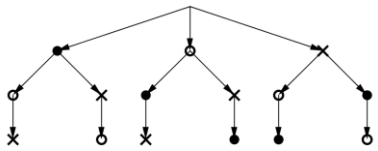
than or equal to zero and less than or equal to one. Also, the probability measure of the sample space must equal one, and the probability measure of the union of multiple outcomes must equal the sum of the individual probability measures.

Probabilities of events are expressed as real numbers from zero to one. They give a numerical value to the chance that a particular event will occur. The probability of an event occurring is the sum of the probabilities of the individual elements of that event. For example, in a standard deck of 52 playing cards as the sample space and the collection of face cards as the event, the probability of drawing a specific face card is $\frac{1}{52} = 0.019$, but the probability of drawing any one of the twelve face cards is $12(0.019) = 0.228$. Note that rounding of numbers can generate different results. If you multiplied 12 by the fraction $\frac{1}{52}$ before converting to a decimal, you would get the answer $\frac{12}{52} = 0.231$.

For a simple sample space, possible outcomes may be determined by using a **tree diagram** or an organized chart. In either case, you can easily draw or list out the possible outcomes. For example, to determine all the possible ways three objects can be ordered, you can draw a tree diagram:



You can also make a chart to list all the possibilities:

First object	Second object	Third object
•	x	o
•	o	x
o	•	x
o	x	•
x	•	o
x	o	•

Either way, you can easily see there are six possible ways the three objects can be ordered.

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If two events have no outcomes in common, they are said to be mutually exclusive. For example, in a standard deck of 52 playing cards, the event of all card suits is mutually exclusive to the event of all card values. If two events have no bearing on each other so that one event occurring has no influence on the probability of another event occurring, the two events are said to be independent. For example, rolling a standard six-sided die multiple times does not change that probability that a particular number will be rolled from one roll to the next. If the outcome of one event does affect the probability of the second event, the two events are said to be dependent. For example, if cards are drawn from a deck, the probability of drawing an ace after an ace has been drawn is different than the probability of drawing an ace if no ace (or no other card, for that matter) has been drawn.

In probability, the odds in favor of an event are the number of times the event will occur compared to the number of times the event will not occur. To calculate the odds in favor of an event, use the formula $\frac{P(A)}{1-P(A)}$, where $P(A)$ is the probability that the event will occur. Many times, odds in favor is given as a ratio in the form $\frac{a}{b}$ or a:b, where a is the probability of the event occurring and b is the complement of the event, the probability of the event not occurring. If the odds in favor are given as 2:5, that means that you can expect the event to occur two times for every 5 times that it does not occur. In other words, the probability that the event will occur is $\frac{2}{2+5} = \frac{2}{7}$.

In probability, the odds against an event are the number of times the event will not occur compared to the number of times the event will occur. To calculate the odds against an event, use the formula $\frac{1-P(A)}{P(A)}$, where $P(A)$ is the probability that the event will occur. Many times, odds against is given as a ratio in the form $\frac{b}{a}$ or b:a, where b is the probability the event will not occur (the complement of the event) and a is the probability the event will occur. If the odds against an event are given as 3:1, that means that you can expect the event to not occur 3 times for every one time it does occur. In other words, 3 out of every 4 trials will fail.

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Statistics

In statistics, the *Population* is the entire collection of people, plants, etc., that data can be collected from. For example, a study to determine how well students in the area schools perform on a standardized test would have a population of all the students enrolled in those schools, although a study may include just a small sample of students from each school. A *Parameter* is a numerical value that gives information about the population, such as the mean, median, mode, or standard deviation. Remember that the symbol for the mean of a population is μ and the symbol for the standard deviation of a population is σ.

A *Sample* is a portion of the entire population. Where as a parameter helped describe the population, a *Statistic* is a numerical value that gives information about the sample, such as mean, median, mode, or standard deviation. Keep in mind that the symbols for mean and standard deviation are different when they are referring to a sample rather than the entire population. For a sample, the symbol for mean is $\bar{x}$ and the symbol for standard deviation is s. The mean and standard deviation of a sample may or may not be identical to that of the entire population due to a sample only being a subset of the population. However, if the sample is random and large enough, statistically significant values can be attained. Samples are generally used when the population is too large to justify including every element or when acquiring data for the entire population is impossible.

Inferential Statistics is the branch of statistics that uses samples to make predictions about an entire population. This type of statistics is often seen in political polls, where a sample of the population is questioned about a particular topic or politician to gain an understanding about the attitudes of the entire population of the country. Often, exit polls are conducted on election days using this method. Inferential statistics can have a large margin of error if you do not have a valid sample.

Statistical values calculated from various samples of the same size make up the sampling distribution. For example, if several samples of identical size are randomly selected from a

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large population and then the mean of each sample is calculated, the distribution of values of the means would be a *Sampling Distribution*.

The *Sampling Distribution of the Mean* is the distribution of the sample mean, $\bar{x}$, derived from random samples of a given size. It has three important characteristics. First, the mean of the sampling distribution of the mean is equal to the mean of the population that was sampled. Second, assuming the standard deviation is non-zero, the standard deviation of the sampling distribution of the mean equals the standard deviation of the sampled population divided by the square root of the sample size. This is sometimes called the standard error. Finally, as the sample size gets larger, the sampling distribution of the mean gets closer to a normal distribution via the Central Limit Theorem.

A *Survey Study* is a method of gathering information from a small group in an attempt to gain enough information to make accurate general assumptions about the population. Once a survey study is completed, the results are then put into a summary report. Survey studies are generally in the format of surveys, interviews, or questionnaires as part of an effort to find opinions of a particular group or to find facts about a group.
It is important to note that the findings from a survey study are only as accurate as the sample chosen from the population.

Correlational Studies seek to determine how much one variable is affected by changes in a second variable. For example, correlational studies may look for a relationship between the amount of time a student spends studying for a test and the grade that student earned on the test or between student scores on college admissions tests and student grades in college.
It is important to note that correlational studies cannot show a cause and effect, but rather can show only that two variables are or are not potentially correlated.

Experimental Studies take correlational studies one step farther, in that they attempt to prove or disprove a cause-and-effect relationship. These studies are performed by

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conducting a series of experiments to test the hypothesis. For a study to be scientifically accurate, it must have both an experimental group that receives the specified treatment and a control group that does not get the treatment. This is the type of study pharmaceutical companies do as part of drug trials for new medications. Experimental studies are only valid when proper scientific method has been followed. In other words, the experiment must be well-planned and executed without bias in the testing process, all subjects must be selected at random, and the process of determining which subject is in which of the two groups must also be completely random.

Observational Studies are the opposite of experimental studies. In observational studies, the tester cannot change or in any way control all of the variables in the test. For example, a study to determine which gender does better in math classes in school is strictly observational. You cannot change a person's gender, and you cannot change the subject being studied. The big downfall of observational studies is that you have no way of proving a cause-and-effect relationship because you cannot control outside influences. Events outside of school can influence a student's performance in school, and observational studies cannot take that into consideration.

For most studies, a *Random Sample* is necessary to produce valid results. Random samples should not have any particular influence to cause sampled subjects to behave one way or another. The goal is for the random sample to be a *Representative Sample*, or a sample whose characteristics give an accurate picture of the characteristics of the entire population. To accomplish this, you must make sure you have a proper *Sample Size*, or an appropriate number of elements in the sample.

In statistical studies, biases must be avoided. *Bias* is an error that causes the study to favor one set of results over another. For example, if a survey to determine how the country views the president's job performance only speaks to registered voters in the president's party, the results will be skewed because a disproportionately large number of responders

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would tend to show approval, while a disproportionately large number of people in the opposite party would tend to express disapproval.

Extraneous Variables are, as the name implies, outside influences that can affect the outcome of a study. They are not always avoidable, but could trigger bias in the result.

Data Analysis

The *Measure of Central Tendency* is a statistical value that gives a general tendency for the center of a group of data. There are several different ways of describing the measure of central tendency. Each one has a unique way it is calculated, and each one gives a slightly different perspective on the data set. Whenever you give a measure of central tendency, always make sure the units are the same. If the data has different units, such as hours, minutes, and seconds, convert all the data to the same unit, and use the same unit in the measure of central tendency. If no units are given in the data, do not give units for the measure of central tendency.

The statistical *Mean* of a group of data is the same as the arithmetic average of that group. To find the mean of a set of data, first convert each value to the same units, if necessary. Then find the sum of all the values, and count the total number of data values, making sure you take into consideration each individual value. If a value appears more than once, count it more than once. Divide the sum of the values by the total number of values and apply the units, if any. Note that the mean does not have to be one of the data values in the set, and may not divide evenly.

$$\text{mean} = \frac{\text{sum of the data values}}{\text{quantity of data values}}$$

While the mean is relatively easy to calculate and averages are understood by most people, the mean can be very misleading if used as the sole measure of central tendency. If the data set has outliers (data values that are unusually high or unusually low compared to the rest of the data values), the mean can be very distorted, especially if the data set has a small number of values. If unusually high values are countered with unusually low values, the

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mean is not affected as much. For example, if five of twenty students in a class get a 100 on a test, but the other 15 students have an average of 60 on the same test, the class average would appear as 70. Whenever the mean is skewed by outliers, it is always a good idea to include the median as an alternate measure of central tendency.

The statistical *Median* is the value in the middle of the set of data. To find the median, list all data values in order from smallest to largest or from largest to smallest. Any value that is repeated in the set must be listed the number of times it appears. If there are an odd number of data values, the median is the value in the middle of the list. If there is an even number of data values, the median is the arithmetic mean of the two middle values.

The statistical *Mode* is the data value that occurs the most number of times in the data set. It is possible to have exactly one mode, more than one mode, or no mode. To find the mode of a set of data, arrange the data like you do to find the median (all values in order, listing all multiples of data values). Count the number of times each value appears in the data set. If all values appear an equal number of times, there is no mode. If one value appears more than any other value, that value is the mode. If two or more values appear the same number of times, but there are other values that appear fewer times and no values that appear more times, all of those values are the modes.

The big disadvantage of using the median as a measure of central tendency is that is relies solely on a value's relative size as compared to the other values in the set. When the individual values in a set of data are evenly dispersed, the median can be an accurate tool. However, if there is a group of rather large values or a group of rather small values that are not offset by a different group of values, the information that can be inferred from the median may not be accurate because the distribution of values is skewed.

The main disadvantage of the mode is that the values of the other data in the set have no bearing on the mode. The mode may be the largest value, the smallest value, or a value anywhere in between in the set. The mode only tells which value or values, if any, occurred

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the most number of times. It does not give any suggestions about the remaining values in the set.

The *Measure of Dispersion* is a single value that helps to "interpret" the measure of central tendency by providing more information about how the data values in the set are distributed about the measure of central tendency. The measure of dispersion helps to eliminate or reduce the disadvantages of using the mean, median, or mode as a single measure of central tendency, and give a more accurate picture of the data set as a whole. To have a measure of dispersion, you must know or calculate the range, standard deviation, or variance of the data set.

The *Range* of a set of data is the difference between the greatest and lowest values of the data in the set. To calculate the range, you must first make sure the units for all data values are the same, and then identify the greatest and lowest values. Use the formula range = highest value – lowest value. If there are multiple data values that are equal for the highest or lowest, just use one of the values in the formula. Write the answer with the same units as the data values you used to do the calculations.

Standard Deviation is a measure of dispersion that compares all the data values in the set to the mean of the set to give a more accurate picture. To find the standard deviation of a population, use the formula

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}}$$

where σ is the standard deviation of a population, x represents the individual values in the data set, $\bar{x}$ is the mean of the data values in the set, and n is the number of data values in the set. The higher the value of the standard deviation is, the greater the variance of the data values from the mean.

The *Variance* of a population, or just variance, is the square of the standard deviation of that population. While the mean of a set of data gives the average of the set and gives

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information about where a specific data value lies in relation to the average, the variance of the population gives information about the degree to which the data values are spread out and tell you how close an individual value is to the average compared to the other values. The units associated with variance are the same as the units of the data values.

Percentiles and Quartiles are other methods of describing data within a set. *Percentiles* tell what percentage of the data in the set fall below a specific point. For example, achievement test scores are often given in percentiles. A score at the 80^{th} percentile is one which is equal to or higher than 80 percent of the scores in the set. In other words, 80 percent of the scores were lower than that score.

Quartiles are percentile groups that make up quarter sections of the data set. The first quartile is the 25^{th} percentile. The second quartile is the 50^{th} percentile; this is also the median of the data set. The third quartile is the 75^{th} percentile.

Skewness is a way to describe the symmetry or asymmetry of the distribution of values in a data set. If the distribution of values is symmetrical, there is no skew. In general the closer the mean of a data set is to the median of the data set, the less skew there is. Generally, if the mean is to the right of the median, the data set is *Positively Skewed*, or right-skewed, and if the mean is to the left of the median, the data set is *negatively skewed*, or left-skewed. However, this rule of thumb is not infallible. When the data values are graphed on a curve, a set with no skew will be a perfect bell curve. To estimate skew, use the formula

$$\text{skew} = \frac{\sqrt{n(n-1)}}{n-2}\left(\frac{\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^3}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2\right)^{\frac{3}{2}}}\right)$$

where n is the number of values is the set, x_i is the i^{th} value in the set, and $\bar{x}$ is the mean of the set.

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In statistics, *Simple Regression* is using an equation to represent a relation between an independent and dependent variables. The independent variable is also referred to as the explanatory variable or the predictor, and is generally represented by the variable x in the equation. The dependent variable, usually represented by the variable y, is also referred to as the response variable. The equation may be any type of function – linear, quadratic, exponential, etc. The best way to handle this task is to use the regression feature of your graphing calculator. This will easily give you the curve of best fit and provide you with the coefficients and other information you need to derive an equation.

In a scatter plot, the *Line of Best Fit* is the line that best shows the trends of the data. The line of best fit is given by the equation $\hat{y} = ax + b$, where a and b are the regression coefficients. The regression coefficient a is also the slope of the line of best fit, and b is also the y-coordinate of the point at which the line of best fit crosses the x-axis. Not every point on the scatter plot will be on the line of best fit. The differences between the y-values of the points in the scatter plot and the corresponding y-values according to the equation of the line of best fit are the residuals. The line of best fit is also called the least-squares regression line because it is also the line that has the lowest sum of the squares of the residuals.

The *Correlation Coefficient* is the numerical value that indicates how strong the relationship is between the two variables of a linear regression equation. A correlation coefficient of –1 is a perfect negative correlation. A correlation coefficient of +1 is a perfect positive correlation. Correlation coefficients close to –1 or +1 are very strong correlations. A correlation coefficient equal to zero indicates there is no correlation between the two variables. This test is a good indicator of whether or not the equation for the line of best fit is accurate. The formula for the correlation coefficient is

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

where r is the correlation coefficient, n is the number of data values in the set, (x_i, y_i) is a point in the set, and $\bar{x}$ and $\bar{y}$ are the means.

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A *Z-score* is an indication of how many standard deviations a given value falls from the mean. To calculate a z-score, use the formula $= \frac{x-\mu}{\sigma}$, where x is the data value, μ is the mean of the data set, and σ is the standard deviation of the population. If the z-score is positive, the data value lies above the mean. If the z-score is negative, the data value falls below the mean. These scores are useful in interpreting data such as standardized test scores, where every piece of data in the set has been counted, rather than just a small random sample. In cases where standard deviations are calculated from a random sample of the set, the z-scores will not be as accurate.

According to the *Central Limit Theorem*, regardless of what the original distribution of a sample is, the distribution of the means tends to get closer and closer to a normal distribution as the sample size gets larger and larger (this is necessary because the sample is becoming more all-encompassing of the elements of the population). As the sample size gets larger, the distribution of the sample mean will approach a normal distribution with a mean of the population mean and a variance of the population variance divided by the sample size.

Important terms

Reactive strategies – are developed after an accident has happened in response to its effects; are often used to created proactive strategies designed to avoid future accidents

Proactive strategies – are developed in order to stop an accident from happening by taking specific steps

Frequency strategies – are a type of proactive strategies which analyze statistical occurrences of accidents in order to determine and address high risk environments or situations

Severity strategies – are designed to specifically address and prevent the type of accidents or situations that cause death, serious illness, affect large quantities of people, or result in significant property damage or destruction

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accident – is an unplanned event or something that happens unexpectedly, often causing undesirable results such as damage, injury, or death

safety – is protection from danger for people or property

risk – is the potential for a negative outcome as a result an action, situation, or scenario; measured subjectively in many cases or objectively if enough statistical data is available

hazard – is a dangerous situation or object that could possibly cause an accident or other negative outcome

safety engineering – is the process of applying the basic tenets of engineering to managing hazards and reducing risks to safety

PHL – means Preliminary Hazard list, a compilation of possible hazards created prior to starting production

PHA – means Preliminary Hazard Analysis, an evaluation of hazardous elements and other safety factors completed in the beginning stages of new product or system design

SSHA – means Subsystem Hazard Analysis, a more in-depth evaluation of elements in a design process including breakdowns of specific parts and human errors, as well as documenting interaction between different parts

OSHA – means Operating and Support Hazard Analysis, an action to identify hazards and consider other options that might decrease risks

OHHA – means Occupational Health Hazard Assessment, an action to pinpoint hazards that might be present for system or product users and those responsible for upkeep and support, as well as to consider ways to decrease risks associated with these hazards

Explosives – are blended chemicals, aggregates, equipment, or apparatus designed to produce detonation

Blasting agents – are substances used to initiate and explosion while at the same time demonstrating stability that makes them unlikely to detonate accidentally

Combustible liquids – are liquid substances that will ignite at temperatures between 100°F and 200°F

Corrosive materials – are any liquid or solid substances capable of causing noticeable harm to human tissues and/or damage to steel

Flammable liquids – are liquid substances that will ignite at temperatures below 100°F

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Flammable gasses – are condensed vapors that have been identified by the Department of Transportation as capable of igniting at lower temperatures or have a greater risk of spreading fire quickly and for great distances if ignited

Primary losses – is the initial $5000 of any one claim or loss

Excess losses – is the amount of money in any one claim or loss that is greater than $5000

Manual rating – insurance premiums or rates applied broadly to certain class of individuals, groups, or organizations based on the insurance company's experiences in claims and/or insurance industry data

Prospective plans – calculate premiums based on a company's past loss history and using experience modifiers to set rates in advance

Retrospective plans – adjust premiums at the end of a fiscal year based on a company's actual losses during the period.

Voluntary risk – is a situation in which a person knowingly and freely, based on personal beliefs and experience, chooses to use a product or engage in an activity after being fully informed of the associated danger of undesirable outcomes

Involuntary risk – is a situation in which a person uses a product or engages in an activity with the associated danger of undesirable effects whose elements are controlled by someone else; the user is unaware or does not have the same understanding of risks as the controlling entity

Relativistic method – this most widely used method of calculating risk begins with a ratings system that separates products into a small number of classes and designates product risks by comparing it to similar products within the designated class

Probabilistic method – this method of calculating risk uses statistical probability that a specified risk will occur with certain frequency given a set number of opportunities and states this probability as a safety level

hazard score – a number calculated from data contained in a hazard checklist; each hazard in the checklist is assigned a point value and hazards which are present figure into the score

control checklist – identifies controls available for use in minimizing hazards; often divides the hazards into different categories to determine scores

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percent risk index – identifies the share of overall risk that is presented by a specific department, stage of operations, job type, or other element

composite risk – a calculation of risk presented by a specific element in an organization or operation such as a department or stage of operation; calculated using the percent risk index and the financial exposure of that specific element

final ranking – organizes each identified element in an organization, such as different departments, according to the risk each presents; helps risk management determine the best use of resources to maximize risk within the overall organization

judgment – is a mental process that involves analyzing information as well as personal convictions and attitudes in order to reach a conclusion about an individual, event, or dilemma; judgmental abilities differ from person to person and are often affected by individual knowledge and experience

emotion – is an individual's feelings in response to a particular stimulus; can be demonstrated through an individual's actions or verbalizations

attitudes – are the result of an individual's personal judgments and emotions based on personal experience; can be positive or negative and are often directly connected to an individual's behavior, but cannot reliably be used to forecast behavior

individual differences – refer to the varying levels of skill, ability, and knowledge that each person possesses; can be transformed by instruction and education

pneumoconiosis – is a disorder or illness of the lungs caused by the inhalation of different kinds of dust and other particulates, often as an occupational hazard; sometimes referred to as black lung or dusty lung

carcinogens – are materials that can cause cancer or promote tumor growth under specific conditions; examples include tobacco smoke and asbestos

mutagens – are materials that can alter the genetic makeup of a person's future offspring or descendents

teratogens – are materials that can contribute to birth defects and deformities in children of people or animals

dermatitis – soreness, swelling, or irritation of the skin caused by a substance or object not part of the body; term commonly used to describe multiple skin disorders

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choloracne – is a condition that resembles dermatitis, but is specifically caused by a reaction of chlorinated napthalenes and polyphenyls in contact with sebaceous glands, and results in an irritation resembling acne

conjunctivitis – is swelling and/or irritation of the eye caused by an object, substance, or injury

PEL – refers to permissible exposure limits and is a measurement commonly used by OSHA to govern worker exposure to certain materials

STEL – refers to short term exposure limits which are generated from a 15 minute exposure

TWA – refers to time weighted average and is used by agencies such as OSHA to define exposure limits for an 8 hour period and establish acceptable work week exposure

TLV – refers to threshold limit value; a list of TLV for most contact substances is generated by The American Conference of Governmental Industrial Hygienists as a resource to help employers reduce worker's risks related to hazardous chemicals

Skin notation – refers to the measurement of TLV for materials that can be absorbed through skin

Ceiling values – establishes an absolute maximum exposure limit that should never be exceeded

Tensile force – force or stress that causes expansion or pulling in different directions

Compression force – force or stress that pinch or compact

Shear force – force or stress that cuts or severs

Torsional force – force or stress that turns, wrenches, twists, or binds

Bending force – force or stress that bends, bows, or arches

Bearing force – pressure of one object on another

Bug – refers to a malfunction or inaccuracy in a computer program

CPU – refers to the central processing unit or brain of the computer which controls all actions performed

Chip – is a small computer component which holds the processor parts such as transistor, diodes, and capacitors

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Code – is information instructing the computer on actions to perform presented in language that the computer understands

Crash – refers to a complete breakdown of the computer's memory and processing systems resulting in loss of vital information

Flowchart – refers to a collection of instructions for the computer to perform n a set order and shown as symbols

Glitch – is a problem or irregularity in a computer system that keeps it from functioning as intended

Hardware – is the physical equipment that carries out the instructions of the computer's CPU

Integrated circuitry – are the lines that carry a low quantity of electricity to the processor

Language – is the method of communication used by the computer to receive directions

Logic – refers to the deliberate process followed by a computer based on the programming it receives

Processor – is the electromechanical elements of the computer that carry out the various functions

Program – refers to the particular directions that software gives a computer to decipher and follow

Software – is a program with coded directions for the computer governing action

Specification – refers to the detailed explanation of the functions or purpose of a specific computer

Sub-program – is also known as a subroutine and is a component of a programs that can be access by the computer if needed for a particular function

Reliability: This is the likelihood that a task will be successfully completed under specified circumstances. Reliability engineers use tools such as effects analysis and failure modes to hypothesize about product reliability. This allows prediction of product failure rates. Failure Modes and Effects Analysis (FMEA) then examines the impact of these failures.

Feasibility: This is the extent to which a particular course is achievable or practical. Analysis of feasibility is costly and time consuming. Minimal levels of analysis are often conducted to determine if more detailed feasibility analysis is warranted. While feasibility

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is an important factor in decision making, it is important not to over-analyze it to the point of losing value.

Validity: This is the extent to which something is accepted as true and reliable. When conducting analysis, validity of the assessment is an important component. Validity of analysis is a function of relying on an extensive data base rather than a few incidents. In product testing, the same results must be produced a number of times before the tests can be deemed valid.

Product liability: This refers to the legal burden that a manufacturer, wholesaler, or retailer holds if its product leads to injuries, property damage, death, or other loss. The three areas of liability that relate to products are warranty, negligence, and strict liability. Warranty is the function of a product in relation to the uses and indications of its manufacturer or seller. Negligence is action of an individual or entity that disregards safety of property or people. Strict liability refers to the nature or condition of a product that is innately hazardous.

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Practice Test

Practice questions

1. According to Heinrich's pyramid theory, for every major accident, how many minor injuries and near-miss incidents will occur?
   a. 29 minor injuries and 300 near-miss incidents
   b. 9 minor injuries and 30 near-miss incidents
   c. 19 minor injuries and 300 near-miss incidents
   d. 29 minor injuries and 350 near-miss incidents

2. According to Haddon's Energy Theory, what element of energy is related to the kind and severity of injuries?
   a. The amount of energy
   b. The means of energy transfer
   c. The rate of energy transfer
   d. All of the above

3. The purpose of a Job Safety Analysis is to:
   a. Develop a training program for new employees
   b. Describe how to perform a job safely and correctly
   c. Identify employees' risk-taking behavior
   d. Analyze normal, routine operations only

4. When should risk identification occur?
   a. Whenever a process changes
   b. Whenever a new employee is trained
   c. On a regular, scheduled basis
   d. Continuously

5. To determine a risk score, Fine's risk assessment and management approach is based on multiplying?
   a. Consequences x Exposure
   b. Consequences x Probability
   c. Exposure x Probability
   d. Consequences x Probability x Exposure

6. The primary purpose for investigating accidents is to:
   a. Compile legal or liability evidence
   b. Assess the degree of damage and value of losses
   c. Prevent future accidents
   d. Identify causes of accidents and injuries

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7. Inductive and deductive expert systems are useful tools for:
   a. Monitoring
   b. Diagnostics
   c. Modeling
   d. Training

8. The most effective way to control tripping hazards is through:
   a. Housekeeping
   b. Architectural changes
   c. Inspection and maintenance
   d. Improved lighting and warning signs

9. High frequency accidents should be investigated because:
   a. Law requires high frequency accidents to be investigated
   b. Investigating high frequency accidents improves customer relations
   c. Investigations can identify patterns of errors and indicate preventive actions
   d. High frequency accidents lead to high losses

10. The Multiple Factor Theory is useful for:
   a. Preventing incidents
   b. Investigating incidents
   c. Identifying hazards
   d. Assessing risks

11. The identifier 29 CFR 1910 refers to:
   a. Section 29 of title 1910 of the Code of Federal Regulations
   b. Section 1910 of title 29 of the Code of Federal Regulations
   c. Page 1910 of title 29 of the Code of Federal Regulations
   d. Page 29 of title 1910 of the Code of Federal Regulations

12. Which agency within the Department of Commerce is responsible for conducting research and developing codes and standards for fire protection and prevention, fire equipment, fire behavior, and consumer and building product safety?
   a. Public Health Services
   b. Consumer Products Safety Commission
   c. National Bureau of Standards
   d. National Institute of Standards and Technology

13. Red books and blue books contain:
   a. Directories of state agencies
   b. Information about voluntary standards developed by ANSI and ASTM
   c. Directories of private laboratories that can provide independent testing and certification
   d. Information about ISO standards

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14. Which of the following techniques can companies use to make managers accountable for safety?
    a. Training of new employees
    b. Detailed safety planning
    c. Cost accounting
    d. All of the above

15. How does redundancy affect hazards?
    a. By eliminating the hazard
    b. By reducing the severity of the hazard
    c. By reducing the probability that the hazard will occur
    d. Redundancy has no effect on hazards

16. If an object places stress of 50 pounds/square inch on a 10 square-inch surface, what is the resulting force?
    a. 2224 newtons
    b. 500 newtons
    c. 5 newtons
    d. 60 newtons

17. When determining the safe load on a floor, live loads indicate:
    a. The weight of the building and its components
    b. Loads placed on the floor
    c. Floor load value in a building code handbook
    d. Load that one joist can bear

18. You are using a Variable Incidence Tribometer to test the slipperiness of wet floors. Which floor is the most slip resistant?
    a. The floor that returns a criterion of .5
    b. The floor that returns a criterion of .7
    c. The floor that returns a criterion of .45
    d. The floor that returns a criterion of .3

19. How tall should a guardrail be in order to protect the greatest number of people from falling?
    a. 45 inches
    b. 36 inches
    c. 48 inches
    d. 42 inches

20. OSHA requires safety belt and lanyard hardware used in fall arresting equipment withstand a tensile load of how much?
    a. 5400 pounds
    b. 5000 pounds
    c. 4000 pounds
    d. 4500 pounds

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21. The preferred slope for stairs is:
    a. 20 degrees from horizontal
    b. 30 degrees from horizontal
    c. 40 degrees from horizontal
    d. 50 degrees from horizontal

22. The Life Safety Code limits the riser height of stairs to:
    a. 7 inches
    b. 4 inches
    c. 11 inches
    d. 5 inches

23. If you are positioning a 20-foot extension ladder against a wall, how far away from the wall should the bottom of the ladder be for maximum safety?
    a. 2 feet
    b. 3 feet
    c. 4 feet
    d. 5 feet

24. On a machine, a pinch point is defined as an opening of what size?
    a. ½ inch
    b. 3/8 inch
    c. 5/8 inch
    d. 2/3 inch

25. Under what circumstances might a guard NOT be needed around mechanical power transmission equipment?
    a. If the equipment is located out of reach of people
    b. If warning signs are posted on and near the equipment
    c. If the equipment includes an emergency shutoff control within reach of the hazardous component
    d. Guards are always needed

26. You are using a pressure sensing device as a guard for a machine. The stopping time of the machine is .05 seconds. What is the safe distance between the sensing point and the point of operation?
    a. 2.25 inches
    b. 3.15 inches
    c. 5.5 inches
    d. There is not enough information to calculate

27. A flammability hazard rating of 3 indicates that:
    a. Materials are readily ignited under almost all conditions
    b. Materials must be moderately heated or exposed to relatively high ambient temperatures before they will ignite
    c. Materials require considerable preheating before ignition and combustion can occur
    d. Materials will not burn under typical fire conditions

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28. At what altitude does a person's ability to see in low-level light become reduced?
    a. 10,000 feet
    b. 8,000 feet
    c. 6,000 feet
    d. 4,000 feet

29. What is the maximum pressure OSHA allows for compressed air for cleaning purposes?
    a. 15 pounds per square inch
    b. 20 pounds per square inch
    c. 25 pounds per square inch
    d. 30 pounds per square inch

30. What must you know about a chemical agent in order to determine if it is hazardous?
    a. Duration and form of exposure
    b. Concentration
    c. What the agent is and what form it is in
    d. All of the above

31. The first priority in an emergency is:
    a. Protecting property
    b. Safeguarding people
    c. Cleanup and salvage
    d. Restoring operations

32. What role do audits play in an occupational safety program?
    a. Audits help determine the overall effectiveness of a safety program
    b. Audits identify hazards that should be addressed in a safety program
    c. Audits identify individuals to take responsibility for aspects of a safety program
    d. Audits do not play a role in an occupational safety program

33. To remove heavy dusts from metal turnings or sand blasting, what should the air velocity be set at for moving contaminants in ducts?
    a. Any velocity
    b. 2500-3500 ft/min
    c. 3500-4000 ft/min
    d. 4000-4500 ft/min

34. A barrel of sludge that is on the EPA list of hazardous wastes and is ignitable and corrosive but does not significantly contribute to mortality or serious irreversible illness would be classified as:
    a. An RCRA solid waste
    b. An RCRA hazardous waste
    c. Not an RCRA hazardous waste
    d. Not an RCRA solid waste

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35. Vibrations in what frequency range may interfere with vision tasks and damage the retina or nerves connected to the eye?

a. 4-8 HZ
b. 20-30 HZ
c. 30-60 HZ
d. 60-90 HZ

36. Portable emergency eyewash fountains must deliver a required flow rate of 1.51/min for how many minutes?

a. 10 minutes
b. 12 minutes
c. 15 minutes
d. 20 minutes

37. The following sign provides what warning?

a. Radiation
b. Ionizing Radiation
c. Non-Ionizing Radiation
d. Chemical Weapon

38. OSHA requires companies to provide training for:

a. New employees
b. Employees who are changing jobs
c. Employees whose jobs have changed
d. All of the above

39. OSHA requires that companies prepare a written Employee Emergency Plan and Fire Emergency Plan unless:

a. They have ten or fewer employees
b. They are on a list of exempt industry types
c. They provide thorough emergency training to all employees on an annual basis
d. They have only one workplace location

40. What industry has the highest level of back injuries in the United States?

a. Manufacturing
b. Construction
c. Agriculture
d. Transportation

41. The most effective type of training for reducing accidents and incidents is:

a. Computer-based training
b. Lecture and video
c. Feedback interventions
d. Behavior modeling

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42. A blue NFPA diamond indicates what danger?
    a. Health hazard
    b. Flammability
    c. Instability
    d. Special hazard

43. A severe hazard is indicated by what number?
    a. 1
    b. 2
    c. 3
    d. 4

44. Relief valves are used primarily for:
    a. Gas
    b. Liquid
    c. Steam
    d. Vapor

45. What portion of the body is at the greatest risk from microwaves?
    a. Brain
    b. Reproductive organs
    c. Eyes
    d. Skin

46. What is the most common route of entry for toxic substances in the work environment?
    a. Inhalation
    b. Injection
    c. Ingestion
    d. Absorption

47. Which of the following government agencies require that work-related incidents, illnesses, and injuries be reported?
    a. OSHA
    b. Mine Safety and Health Administration
    c. Nuclear Regulatory Commission
    d. All of the above

48. What concentration of carbon monoxide can cause death?
    a. 1%
    b. 5%
    c. 10%
    d. 15%

49. What is the best type of visual display to use when presenting information in which trends are important?
    a. Pie charts
    b. Line graphs
    c. Tables
    d. Stacked bar charts

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50. According to OSHA, who bears the burden for ensuring that employees have the correct personal protective equipment for a hazard?

a. The employer
b. The employee
c. OSHA inspectors
d. The manufacturer of the PPE

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Answers and explanations

1. A: Heinrich's pyramid theory states that for every major accident, there are 29 minor accidents and 300 near-miss incidents. According to this theory, safety managers should focus on preventing less serious events in order to prevent more serious events.

2. D: All of these factors affect the kind and severity of injuries. Losses can be prevented or reduced by strategies like reducing the production of energy, reducing the amount of energy marshaled, preventing the release of energy, and modifying the rate at which energy is released.

3. B: The primary purpose of a Job Safety Analysis is to describe how to perform a job safely and correctly. The analysis can be used to develop training programs, user manuals, and operations manuals. It should analyze both normal operations and unusual activities and conditions.

4. D: Risk analysis should occur continuously because risk changes over time. The goal is to identify hazards and determine what components contribute to injury or illness.

5. D: Fine's formula is R=C x E x P, where C is the consequences, E is exposure, and P is probability. Fine developed a classification rating table to provide values for each category. The resulting risk score can then be used to develop a cost justification value with the formula J=R/(CF x DC), where CF is a cost factor and DC is a degree of correction.

6. C: While an accident investigation can have several purposes, the primary purpose is always to prevent future accidents.

7. B: Expert systems are useful for diagnostics, helping someone with little knowledge of a topic to make a decision.

8. A: While all of these options can help reduce tripping hazards, good housekeeping is often all that is necessary. Tools should be replaced, waste disposed of and objects kept out of the walking zone.

9. C: Patterns identified when investigating high frequency accidents can indicate potential preventive actions. High frequency accidents can often be identified through accident and incident reports, customer complaints, field reports, and work orders.

10. A: The Multiple Factor Theory is useful for preventing incidents. Safety managers identify four factors: man, media, machine, and management. The goal is to identify the factors that an operation or activity uses and what combination is most likely to result in an incident.

11. B: 29 CFR 1910 refers to Title 29 of the Code of Federal Regulations, with 1910 referring to a section within this title. Title 29 refers to OSHA documents; this particular section deals with general industry.

12. D: The National Institute of Standards and Technology was formerly known as the National Bureau of Standards.

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13. A: Red and blue books are common names for state government directories that list agencies and their general responsibilities. These directories are useful in identifying sources of information.

14. D: All of these techniques serve to make managers accountable for safety. Employee training and safety planning help to eliminate the factors that cause an unsafe environment. Putting managers in charge of these gives them accountability on the front end. Cost accounting requires keeping track of safety costs, such as lost wages, cost of accident investigation, and uninsured medical costs.

15. C: Redundancy reduces the probability that a hazard will occur by providing more than one independent means to accomplish something. Redundancy can be provided by installing two or more parallel components in a system or by installing a backup system.

16. A: The formula for calculating force is F=sA, where s is stress (force per unit area) and A is the area over which the force acts. In order to calculate the force, you must convert the stress from pounds/square inch to newtons/square meter and the area from square inches to square meter.

17. B: Live loads are the loads placed on a floor. Live loads will vary in different types of buildings, such as office buildings versus parking lots.

18. B: With the Variable Incidence Tribometer, floors measuring higher than .5 are considered slip-resistant, while those measuring lower than .5 are not slip-resistant.

19. D: A guardrail should be at least 42 inches from a floor in order to protect the greatest number of people. OSHA requires a 42 inch height for guardrails.

20. C: Safety belt and lanyard hardware used in fall arresting equipment must withstand a tensile load of 4000 pounds. Anchors and lifelines must withstand a load of 5400 pounds.

21. B: The preferred slope for stairs is 30-35 degrees from the horizontal, although standards allow slopes to fall from 20 to 50 degrees from horizontal.

22. A: The Life Safety Code specifies the maximum height of a stair riser is 7 inches and the minimum height is 4 inches. The minimum tread depth is 11 inches.

23. D: When placing a ladder, the horizontal distance from the wall to the legs should be ¼ of the height of the ladder. If the distance is too small, the ladder can tip backwards and if it is too large, the ladder can slide out at the bottom.

24. B: A pinch point is an opening that is 3/8 inch in diameter, or about the thickness of a human finger.

25. A: A guard might not be needed around mechanical power transmission equipment if the equipment is located out of reach of people. This is usually defined as at least 7-8 feet high with access only available to trained workers.

26. B: The formula for calculating safe distance is D=63 in/s x T, where D equals distances, 63 is a constant representing hand speed, and T is the stopping time of the machine in seconds.

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27. A: A flammability hazard rating of 3 indicates that materials are readily ignited under almost all conditions. Flammability hazard ratings range from 0 (materials will not burn under typical fire conditions) to 4 (materials are readily dispersed in air and will burn readily).

28. C: Ability to see in low light begins to diminish at around 6,000 feet. This is one of the first signs of hypoxia, which is a lack of metabolic oxygen. As altitude increases, further effects include impaired memory, coordination, and judgment; euphoria; drowsiness; unconsciousness; and death.

29. D: Compressed air for cleaning purposes must be 30 pounds per square inch or less in order to minimize danger to users. Pressure-reducing nozzles can be used to reduce the air pressure to acceptable levels.

30. D: You must know all of this information in order to determine if a chemical agent is hazardous. The main hazards of chemicals are reactivity with other materials, health effects, fire and explosion.

31. B: The first priority in an emergency is the safety of people, whether visitors, employees, customers, or the general public. Caring for the injured and evacuating people who could be injured are the highest priority in all situations.

32. A: Audits help determine the overall effectiveness of a safety program. Through an audit, safety managers can determine if the company is complying with safety standards, plans, and programs.

33. D: To move heavy dust through a duct, the air velocity should be set at 4000 to 4500 ft/min. If the velocity is too low, the contaminants can settle and plug the duct, while a velocity that is too high can dent the duct and potentially lead to leaks.

34. C: The EPA defines a hazardous waste as any material that meets the RCRA definition of a solid waste and is not excluded as a hazardous waste. To be classified as an RCRA hazardous waste, a material must be an RCRA solid waste that is on the EPA list of hazardous materials and also contributes to an increase in mortality or serious illness or poses a substantial hazard to human health or the environment when improperly managed.

35. D: Eyes have natural or resonant frequency of 60-90 HZ. Vibrations in this frequency may interfere with vision and cause damage to the eyes. In addition, large amplitudes can damage supporting muscles and ligaments.

36. C: Portable emergency eyewash fountains must deliver flow for 15 minutes, while fixed units have unlimited water supplies. These fountains deliver streams of water upward into each eye, making them preferable to an emergency shower, in which the flow is downward.

37. B: This sign warns of ionizing radiation. It replaced the trefoil symbol, which was not easily recognized as indicating danger.

38. D: OSHA requires training in all these circumstances. New employees require training in order to develop safe work habits, while training experienced employees who are starting new jobs can help them identify and correct unsafe work habits.

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39. A: Companies do not need to prepare a written Employee Emergency Plan and Fire Emergency Plan if they have ten or fewer employees. These companies can communicate their emergency plans orally.

40. B: The number of back injuries reported by construction workers is 50% higher than the average for all other U.S. industries.

41. D: Workers who participate in hands-on training activities such as behavior modeling have the greatest reduction in accidents and injuries. Behavioral modeling involves observing a role model and then practicing techniques and receiving feedback.

42. A: A blue NFPA diamond indicates a health hazard. Red diamonds indicate flammability, yellow indicates instability, and white is for special hazards.

43. D: NFPA hazards are indicated on a scale of 0 to 4, with 4 indicating a severe hazard and 0 indicating no hazard.

44. B: Relief valves are primarily used for liquids. Relief valves open in proportion to the amount of overpressure and close when the pressure returns to acceptable levels.

45. C: Eyes are at the greatest danger from microwaves, which have a cumulative effect on the eyes' lenses and can lead to cataracts.

46. A: Inhalation is the most common route of entry for toxins in the workplace. Once the toxin enters the body, it is absorbed into the blood and distributed throughout the body.

47. D: All three of these agencies require that work-related incidents, illnesses, and injuries be reported. OSHA requires that companies with more than ten employees log reportable incidents and submit an annual summary. MSHA requires a report for each incident and for each injured or ill person. The NRC requires that reports of excessive exposure to ionizing radiation be made within 24 hours or 30 days, depending on the severity of the incident.

48. A: A 1% concentration of carbon monoxide can cause death in one minute or less. Because carbon monoxide can cause death so quickly and at relatively low concentrations, it is a major cause of death in fires.

49. B: Line graphs are the best type of visual display to use when presenting information in which trends are important. Pie charts are best for showing portions of a whole; tables are useful for presenting precise data; and stacked bar charts show how each unit contributes to the total for a specific time or topic.

50. A: OSHA places the burden for PPE on the employer. Even if the employee purchases his or her own PPE, the employer must ensure that the PPE is the correct choice for the hazard, is in good condition, works correctly, and fits properly.

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Pace Yourself

Wear a watch. At the beginning of the test, check the time (or start a chronometer on your watch to count the minutes), and check the time after every few questions to make sure you are "on schedule."

If you are forced to speed up, do it efficiently. Usually one or more answer choices can be eliminated without too much difficulty. Above all, don't panic. Don't speed up and just begin guessing at random choices. By pacing yourself, and continually monitoring your progress against your watch, you will always know exactly how far ahead or behind you are with your available time. If you find that you are one minute behind on the test, don't skip one question without spending any time on it, just to catch back up. Take 15 fewer seconds on the next four questions, and after four questions you'll have caught back up. Once you catch back up, you can continue working each problem at your normal pace.

Furthermore, don't dwell on the problems that you were rushed on. If a problem was taking up too much time and you made a hurried guess, it must be difficult. The difficult questions are the ones you are most likely to miss anyway, so it isn't a big loss. It is better to end with more time than you need than to run out of time.

Lastly, sometimes it is beneficial to slow down if you are constantly getting ahead of time. You are always more likely to catch a careless mistake by working more slowly than quickly, and among very high-scoring test takers (those who are likely to have lots of time left over), careless errors affect the score more than mastery of material.

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Secret Key #2 - Guessing is not Guesswork

You probably know that guessing is a good idea - unlike other standardized tests, there is no penalty for getting a wrong answer. Even if you have no idea about a question, you still have a 20-25% chance of getting it right.

Most test takers do not understand the impact that proper guessing can have on their score. Unless you score extremely high, guessing will significantly contribute to your final score.

Monkeys Take the Test

What most test takers don't realize is that to insure that 20-25% chance, you have to guess randomly. If you put 20 monkeys in a room to take this test, assuming they answered once per question and behaved themselves, on average they would get 20-25% of the questions correct. Put 20 test takers in the room, and the average will be much lower among guessed questions. Why?

1. The test writers intentionally write deceptive answer choices that "look" right. A test taker has no idea about a question, so picks the "best looking" answer, which is often wrong. The monkey has no idea what looks good and what doesn't, so will consistently be lucky about 20-25% of the time.
2. Test takers will eliminate answer choices from the guessing pool based on a hunch or intuition. Simple but correct answers often get excluded, leaving a 0% chance of being correct. The monkey has no clue, and often gets lucky with the best choice.

This is why the process of elimination endorsed by most test courses is flawed and detrimental to your performance- test takers don't guess, they make an ignorant stab in the dark that is usually worse than random.

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$5 Challenge

Let me introduce one of the most valuable ideas of this course- the $5 challenge:

You only mark your "best guess" if you are willing to bet $5 on it.
You only eliminate choices from guessing if you are willing to bet $5 on it.

Why $5? Five dollars is an amount of money that is small yet not insignificant, and can really add up fast (20 questions could cost you $100). Likewise, each answer choice on one question of the test will have a small impact on your overall score, but it can really add up to a lot of points in the end.

The process of elimination IS valuable. The following shows your chance of guessing it right:

If you eliminate wrong answer choices until only this many remain:	1	2	3
Chance of getting it correct:	100%	50%	33%

However, if you accidentally eliminate the right answer or go on a hunch for an incorrect answer, your chances drop dramatically: to 0%. By guessing among all the answer choices, you are GUARANTEED to have a shot at the right answer.

That's why the $5 test is so valuable- if you give up the advantage and safety of a pure guess, it had better be worth the risk.

What we still haven't covered is how to be sure that whatever guess you make is truly random. Here's the easiest way:

Always pick the first answer choice among those remaining.

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Such a technique means that you have decided, **before you see a single test question**, exactly how you are going to guess- and since the order of choices tells you nothing about which one is correct, this guessing technique is perfectly random.

This section is not meant to scare you away from making educated guesses or eliminating choices- you just need to define when a choice is worth eliminating. The $5 test, along with a pre-defined random guessing strategy, is the best way to make sure you reap all of the benefits of guessing.

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Secret Key #3 - Practice Smarter, Not Harder

Many test takers delay the test preparation process because they dread the awful amounts of practice time they think necessary to succeed on the test. We have refined an effective method that will take you only a fraction of the time.

There are a number of "obstacles" in your way to succeed. Among these are answering questions, finishing in time, and mastering test-taking strategies. All must be executed on the day of the test at peak performance, or your score will suffer. The test is a mental marathon that has a large impact on your future.

Just like a marathon runner, it is important to work your way up to the full challenge. So first you just worry about questions, and then time, and finally strategy:

Success Strategy

1. Find a good source for practice tests.
2. If you are willing to make a larger time investment, consider using more than one study guide- often the different approaches of multiple authors will help you "get" difficult concepts.
3. Take a practice test with no time constraints, with all study helps "open book." Take your time with questions and focus on applying strategies.
4. Take a practice test with time constraints, with all guides "open book."
5. Take a final practice test with no open material and time limits

If you have time to take more practice tests, just repeat step 5. By gradually exposing yourself to the full rigors of the test environment, you will condition your mind to the stress of test day and maximize your success.

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Secret Key #4 - Prepare, Don't Procrastinate

Let me state an obvious fact: if you take the test three times, you will get three different scores. This is due to the way you feel on test day, the level of preparedness you have, and, despite the test writers' claims to the contrary, some tests WILL be easier for you than others.

Since your future depends so much on your score, you should maximize your chances of success. In order to maximize the likelihood of success, you've got to prepare in advance. This means taking practice tests and spending time learning the information and test taking strategies you will need to succeed.

Never take the test as a "practice" test, expecting that you can just take it again if you need to. Feel free to take sample tests on your own, but when you go to take the official test, be prepared, be focused, and do your best the first time!

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Secret Key #5 - Test Yourself

Everyone knows that time is money. There is no need to spend too much of your time or too little of your time preparing for the test. You should only spend as much of your precious time preparing as is necessary for you to get the score you need.

Once you have taken a practice test under real conditions of time constraints, then you will know if you are ready for the test or not.

If you have scored extremely high the first time that you take the practice test, then there is not much point in spending countless hours studying. You are already there.

Benchmark your abilities by retaking practice tests and seeing how much you have improved. Once you score high enough to guarantee success, then you are ready.

If you have scored well below where you need, then knuckle down and begin studying in earnest. Check your improvement regularly through the use of practice tests under real conditions. Above all, don't worry, panic, or give up. The key is perseverance!

Then, when you go to take the test, remain confident and remember how well you did on the practice tests. If you can score high enough on a practice test, then you can do the same on the real thing.

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General Strategies

The most important thing you can do is to ignore your fears and jump into the test immediately- do not be overwhelmed by any strange-sounding terms. You have to jump into the test like jumping into a pool- all at once is the easiest way.

Make Predictions

As you read and understand the question, try to guess what the answer will be. Remember that several of the answer choices are wrong, and once you begin reading them, your mind will immediately become cluttered with answer choices designed to throw you off. Your mind is typically the most focused immediately after you have read the question and digested its contents. If you can, try to predict what the correct answer will be. You may be surprised at what you can predict.

Quickly scan the choices and see if your prediction is in the listed answer choices. If it is, then you can be quite confident that you have the right answer. It still won't hurt to check the other answer choices, but most of the time, you've got it!

Answer the Question

It may seem obvious to only pick answer choices that answer the question, but the test writers can create some excellent answer choices that are wrong. Don't pick an answer just because it sounds right, or you believe it to be true. It MUST answer the question. Once you've made your selection, always go back and check it against the question and make sure that you didn't misread the question, and the answer choice does answer the question posed.

Benchmark

After you read the first answer choice, decide if you think it sounds correct or not. If it doesn't, move on to the next answer choice. If it does, mentally mark that answer choice. This doesn't mean that you've definitely selected it as your answer choice; it just means

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that it's the best you've seen thus far. Go ahead and read the next choice. If the next choice is worse than the one you've already selected, keep going to the next answer choice. If the next choice is better than the choice you've already selected, mentally mark the new answer choice as your best guess.

The first answer choice that you select becomes your standard. Every other answer choice must be benchmarked against that standard. That choice is correct until proven otherwise by another answer choice beating it out. Once you've decided that no other answer choice seems as good, do one final check to ensure that your answer choice answers the question posed.

Valid Information

Don't discount any of the information provided in the question. Every piece of information may be necessary to determine the correct answer. None of the information in the question is there to throw you off (while the answer choices will certainly have information to throw you off). If two seemingly unrelated topics are discussed, don't ignore either. You can be confident there is a relationship, or it wouldn't be included in the question, and you are probably going to have to determine what that relationship is to find the answer.

Avoid "Fact Traps"

Don't get distracted by a choice that is factually true. Your search is for the answer that answers the question. Stay focused and don't fall for an answer that is true but incorrect. Always go back to the question and make sure you're choosing an answer that actually answers the question and is not just a true statement. An answer can be factually correct, but it MUST answer the question asked. Additionally, two answers can both be seemingly correct, so be sure to read all of the answer choices, and make sure that you get the one that BEST answers the question.

Milk the Question

Some of the questions may throw you completely off. They might deal with a subject you have not been exposed to, or one that you haven't reviewed in years. While your lack of

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knowledge about the subject will be a hindrance, the question itself can give you many clues that will help you find the correct answer. Read the question carefully and look for clues. Watch particularly for adjectives and nouns describing difficult terms or words that you don't recognize. Regardless of if you completely understand a word or not, replacing it with a synonym either provided or one you more familiar with may help you to understand what the questions are asking. Rather than wracking your mind about specific detailed information concerning a difficult term or word, try to use mental substitutes that are easier to understand.

The Trap of Familiarity

Don't just choose a word because you recognize it. On difficult questions, you may not recognize a number of words in the answer choices. The test writers don't put "make-believe" words on the test; so don't think that just because you only recognize all the words in one answer choice means that answer choice must be correct. If you only recognize words in one answer choice, then focus on that one. Is it correct? Try your best to determine if it is correct. If it is, that is great, but if it doesn't, eliminate it. Each word and answer choice you eliminate increases your chances of getting the question correct, even if you then have to guess among the unfamiliar choices.

Eliminate Answers

Eliminate choices as soon as you realize they are wrong. But be careful! Make sure you consider all of the possible answer choices. Just because one appears right, doesn't mean that the next one won't be even better! The test writers will usually put more than one good answer choice for every question, so read all of them. Don't worry if you are stuck between two that seem right. By getting down to just two remaining possible choices, your odds are now 50/50. Rather than wasting too much time, play the odds. You are guessing, but guessing wisely, because you've been able to knock out some of the answer choices that you know are wrong. If you are eliminating choices and realize that the last answer choice you are left with is also obviously wrong, don't panic. Start over and consider each choice again. There may easily be something that you missed the first time and will realize on the second pass.

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Tough Questions

If you are stumped on a problem or it appears too hard or too difficult, don't waste time. Move on! Remember though, if you can quickly check for obviously incorrect answer choices, your chances of guessing correctly are greatly improved. Before you completely give up, at least try to knock out a couple of possible answers. Eliminate what you can and then guess at the remaining answer choices before moving on.

Brainstorm

If you get stuck on a difficult question, spend a few seconds quickly brainstorming. Run through the complete list of possible answer choices. Look at each choice and ask yourself, "Could this answer the question satisfactorily?" Go through each answer choice and consider it independently of the other. By systematically going through all possibilities, you may find something that you would otherwise overlook. Remember that when you get stuck, it's important to try to keep moving.

Read Carefully

Understand the problem. Read the question and answer choices carefully. Don't miss the question because you misread the terms. You have plenty of time to read each question thoroughly and make sure you understand what is being asked. Yet a happy medium must be attained, so don't waste too much time. You must read carefully, but efficiently.

Face Value

When in doubt, use common sense. Always accept the situation in the problem at face value. Don't read too much into it. These problems will not require you to make huge leaps of logic. The test writers aren't trying to throw you off with a cheap trick. If you have to go beyond creativity and make a leap of logic in order to have an answer choice answer the question, then you should look at the other answer choices. Don't overcomplicate the problem by creating theoretical relationships or explanations that will warp time or space. These are normal problems rooted in reality. It's just that the applicable relationship or explanation may not be readily apparent and you have to figure things out. Use your common sense to interpret anything that isn't clear.

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Prefixes

If you're having trouble with a word in the question or answer choices, try dissecting it. Take advantage of every clue that the word might include. Prefixes and suffixes can be a huge help. Usually they allow you to determine a basic meaning. Pre- means before, post- means after, pro - is positive, de- is negative. From these prefixes and suffixes, you can get an idea of the general meaning of the word and try to put it into context. Beware though of any traps. Just because con is the opposite of pro, doesn't necessarily mean congress is the opposite of progress!

Hedge Phrases

Watch out for critical "hedge" phrases, such as likely, may, can, will often, sometimes, often, almost, mostly, usually, generally, rarely, sometimes. Question writers insert these hedge phrases to cover every possibility. Often an answer choice will be wrong simply because it leaves no room for exception. Avoid answer choices that have definitive words like "exactly," and "always".

Switchback Words

Stay alert for "switchbacks". These are the words and phrases frequently used to alert you to shifts in thought. The most common switchback word is "but". Others include although, however, nevertheless, on the other hand, even though, while, in spite of, despite, regardless of.

New Information

Correct answer choices will rarely have completely new information included. Answer choices typically are straightforward reflections of the material asked about and will directly relate to the question. If a new piece of information is included in an answer choice that doesn't even seem to relate to the topic being asked about, then that answer choice is likely incorrect. All of the information needed to answer the question is usually provided for you, and so you should not have to make guesses that are unsupported or choose answer choices that require unknown information that cannot be reasoned on its own.

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Time Management

On technical questions, don't get lost on the technical terms. Don't spend too much time on any one question. If you don't know what a term means, then since you don't have a dictionary, odds are you aren't going to get much further. You should immediately recognize terms as whether or not you know them. If you don't, work with the other clues that you have, the other answer choices and terms provided, but don't waste too much time trying to figure out a difficult term.

Contextual Clues

Look for contextual clues. An answer can be right but not correct. The contextual clues will help you find the answer that is most right and is correct. Understand the context in which a phrase or statement is made. This will help you make important distinctions.

Don't Panic

Panicking will not answer any questions for you. Therefore, it isn't helpful. When you first see the question, if your mind goes blank, take a deep breath. Force yourself to mechanically go through the steps of solving the problem and using the strategies you've learned.

Pace Yourself

Don't get clock fever. It's easy to be overwhelmed when you're looking at a page full of questions, your mind is full of random thoughts and feeling confused, and the clock is ticking down faster than you would like. Calm down and maintain the pace that you have set for yourself. As long as you are on track by monitoring your pace, you are guaranteed to have enough time for yourself. When you get to the last few minutes of the test, it may seem like you won't have enough time left, but if you only have as many questions as you should have left at that point, then you're right on track!

Answer Selection

The best way to pick an answer choice is to eliminate all of those that are wrong, until only one is left and confirm that is the correct answer. Sometimes though, an answer choice

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may immediately look right. Be careful! Take a second to make sure that the other choices are not equally obvious. Don't make a hasty mistake. There are only two times that you should stop before checking other answers. First is when you are positive that the answer choice you have selected is correct. Second is when time is almost out and you have to make a quick guess!

Check Your Work

Since you will probably not know every term listed and the answer to every question, it is important that you get credit for the ones that you do know. Don't miss any questions through careless mistakes. If at all possible, try to take a second to look back over your answer selection and make sure you've selected the correct answer choice and haven't made a costly careless mistake (such as marking an answer choice that you didn't mean to mark). This quick double check should more than pay for itself in caught mistakes for the time it costs.

Beware of Directly Quoted Answers

Sometimes an answer choice will repeat word for word a portion of the question or reference section. However, beware of such exact duplication – it may be a trap! More than likely, the correct choice will paraphrase or summarize a point, rather than being exactly the same wording.

Slang

Scientific sounding answers are better than slang ones. An answer choice that begins "To compare the outcomes…" is much more likely to be correct than one that begins "Because some people insisted…"

Extreme Statements

Avoid wild answers that throw out highly controversial ideas that are proclaimed as established fact. An answer choice that states the "process should be used in certain situations, if…" is much more likely to be correct than one that states the "process should be discontinued completely." The first is a calm rational statement and doesn't even make

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a definitive, uncompromising stance, using a hedge word "if" to provide wiggle room, whereas the second choice is a radical idea and far more extreme.

Answer Choice Families

When you have two or more answer choices that are direct opposites or parallels, one of them is usually the correct answer. For instance, if one answer choice states "x increases" and another answer choice states "x decreases" or "y increases," then those two or three answer choices are very similar in construction and fall into the same family of answer choices. A family of answer choices is when two or three answer choices are very similar in construction, and yet often have a directly opposite meaning. Usually the correct answer choice will be in that family of answer choices. The "odd man out" or answer choice that doesn't seem to fit the parallel construction of the other answer choices is more likely to be incorrect.

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ISBN 978-1-60971-581-6
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